







LABORATORY DIRECTIONS AND STUDY QUESTIONS  
IN  
INORGANIC CHEMISTRY

By  
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AND  
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INSTRUCTOR IN INORGANIC CHEMISTRY

—  
*ILLUSTRATED*  
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# I. INTERNATIONAL ATOMIC WEIGHTS

O = 16.00

Name	Symbol	Atomic Weight	Name	Symbol	Atomic Weight
Aluminum.....	Al	27.1	Molybdenum.....	Mo	96.0
Antimony.....	Sb	120.3	Neodymium.....	Nd	144.3
Argon.....	A	39.83	Neon.....	Ne	20.2
Arsenic.....	As	74.96	Nickel.....	Ni	58.68
Barium.....	Ba	137.37	Niton.....	Nt	222.4
Bismuth.....	Bi	208.0	Nitrogen.....	N	14.01
Boron.....	B	11.0	Osmium.....	Os	190.9
Bromine.....	Br	79.92	Oxygen.....	O	16.00
Cadmium.....	Cd	112.40	Palladium.....	Pd	106.7
Caesium.....	Cs	132.81	Phosphorus.....	P	31.04
Calcium.....	Ca	40.07	Platinum.....	Pt	195.2
Carbon.....	C	12.005	Potassium.....	K	39.10
Cerium.....	Ce	140.25	Praseodymium.....	Pr	140.9
Chlorine.....	Cl	35.46	Radium.....	Ra	226.0
Chromium.....	Cr	52.0	Rhodium.....	Rh	102.9
Cobalt.....	Co	58.97	Rubidium.....	Rb	85.45
Columbium.....	Cb	93.1	Ruthenium.....	Ru	101.7
Copper.....	Cu	63.57	Samarium.....	Sa	150.4
Dysprosium.....	Dy	162.5	Scandium.....	Sc	44.1
Erbium.....	Er	167.7	Selenium.....	Se	79.2
Europium.....	Eu	152.0	Silicon.....	Si	28.3
Fluorine.....	F	19.0	Silver.....	Ag	107.88
Gadolinium.....	Gd	157.3	Sodium.....	Na	23.00
Gallium.....	Ga	69.9	Strontium.....	Sr	87.63
Germanium.....	Ge	72.5	Sulphur.....	S	32.06
Glucinum.....	Gl	9.1	Tantalum.....	Ta	181.5
Gold.....	Au	197.2	Tellurium.....	Te	127.5
Helium.....	He	4.00	Terbium.....	Tb	159.2
Holmium.....	Ho	163.5	Thallium.....	Tl	204.0
Hydrogen.....	H	1.008	Thorium.....	Th	232.4
Indium.....	In	114.8	Thulium.....	Tm	168.5
Iridium.....	Ir	193.1	Tin.....	Sn	118.7
Iodine.....	I	126.92	Titanium.....	Ti	48.1
Iron.....	Fe	55.84	Tungsten.....	W	184.0
Krypton.....	Kr	82.92	Uranium.....	U	238.2
Lanthanum.....	La	139.0	Vanadium.....	V	51.0
Lead.....	Pb	207.20	Xenon.....	Xe	130.2
Lithium.....	Li	6.94	Ytterbium.....	Yb	173.5
Lutecium.....	Lu	175.0	(Neoytterbium)		
Magnesium.....	Mg	24.32	Yttrium.....	Yt	88.7
Manganese.....	Mn	54.93	Zinc.....	Zn	65.37
Mercury.....	Hg	200.6	Zirconium.....	Zr	90.6

Compiled by the International Committee on Atomic Weights, consisting of F. W. Clarke, T. E. Thorpe and G. Urbain. J. Am. Chem. Soc., 38, 2220.

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31 ILLUSTRATIONS



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## FOREWORD

The following loose-leaf *Laboratory Directions* which have been tried and corrected in our laboratories for the past five years are now presented in printed form for the benefit of other institutions. In the University of Pittsburgh the student will, on an average, complete one set of experiments per three-hour period. He is scheduled for two such periods per week throughout the college year.

Results are noted on a separate sheet and submitted with the instruction sheet at the end of each period. Both the direction sheet and record sheet are stamped by the instructor before they are returned to the student.

A word should be said about the *study questions* which constitute the second half of this volume. These serve as a study guide for the student. Questions of major importance are starred. All recitations and examinations are conducted on the basis of these questions so that a uniform system is employed even where a dozen or more instructors handle different sections. The method has met with such marked success here that there is no doubt about its success when introduced into other institutions.

The authors will welcome notice of errors found in this volume and invite suggestions from those who have occasion to use it.

School of Chemistry,  
University of Pittsburgh,  
Sept. 1, 1919.

ALEXANDER SILVERMAN.  
ADELBERT W. HARVEY.



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## ERRATA

Leaf 9, Experiment 41, line 5: *For* experiment 20 *read* experiment 29.

“ 9, “ 41, “ 6: *For* experiment 35 *read* experiment 34.

“ 16, “ 65, “ 19: *For* in 61 *read* in 60.

“ 16, “ 65, “ 21: *For* in 65 *read* in 64.

“ 19, “ 77, “ 8: *For* experiment 77 *read* experiment 76.

“ 27, “ 109, “ 2: *For* Erlenmeyer flask (E) *read* Erlenmeyer flask (B).

“ 28, “ 112, “ 13: *For* HCl and NaCl *read* HCl on NaCl.

“ 31, “ 125, “ 33: *For*  $3\text{Fe}_2(\text{SO}_4)_3 + 3\text{H}_2\text{O} + 2\text{NO}$  *read*  $3\text{Fe}_2(\text{SO}_4)_3 + 4\text{H}_2\text{O} + 2\text{NO}$ .

“ 38, “ 161, “ 18: *For* dilute solution *read* dilute solutions.

“ 45, “ 194, “ 13: *Should be* (.) *after* on the reaction.

## STUDY QUESTIONS

Leaf 70, Question 34: *Should read as follows:* One liter of bromine weighs 3180 grams. What is its specific gravity?

“ 75, “ 17: *For* H5 *read* HS<sup>-</sup>.

“ 76, “ 26: *Should be followed by* (?) *instead of by* (.).







## LABORATORY RULES

(These rules apply in the University of Pittsburgh but may be modified to meet the needs of other institutions.)

Secure locker assignment from laboratory instructor and deposit a \$5.00 coupon book with him, securing a receipt for same.

Place all apparatus found in locker and drawers on your desk. Stow away each article checking it by the apparatus list attached to the locker door. Make a list of shortage or broken pieces and obtain an order for same from your instructor. If any apparatus is broken during the semester *replace it immediately*.

Purchase the non-returnable apparatus, listed on the slip in your drawer at the supply room.

Each student should keep himself provided with an apron, a sponge, soap and a towel or two. The sponge and towel may be obtained at the supply room.

Each student should keep his desk and apparatus clean and at the close of each period should leave the desk dry and locker and drawers in order. *Do not put away apparatus unwashed.*

Do not mix reagents except as directed. Follow instructions closely but not blindly.

Pour *liquids only* into sinks. You are responsible for the condition of the sink nearest your desk. The statement that someone else got it out of order is not acceptable. Do not throw match sticks, filter papers or broken glass into the sink. Place *all waste solids in crocks* provided for that purpose.

Under no circumstances may reagent bottles be taken from the general shelves or from one desk to another. You will find on your desk a set of reagents more commonly used. Any others required you may, by consulting the charts, find in their numbered places on the general reagent shelves. Duplicate sets of wet and dry reagents are on either side of the laboratory. Removing these bottles from their numbered places is *not* "helping the other student."

To obtain necessary chemical substances which are not found on your desk, bring to the side shelves a clean test-tube for liquids or a piece of clean paper for solids. When too much of a reagent is taken from a bottle do not pour it back, thereby possibly contaminating the remaining contents.

In case of fire cover the flame with a towel or apron. Do not attempt to blow it out. If more serious, have the instructor use a fire extinguisher. Should your clothing catch fire, extinguish same by wrapping a blanket about yourself.

Wash slight acid burns or wounds thoroughly with water, moisten a handkerchief with sodium bicarbonate solution and bind on the part affected. For alkali burns use boric acid. If the accident is more serious *see an instructor at once*.

Enter and leave the laboratory promptly on schedule time. Lock up apparatus issued to you and for which you have receipted. Do not lock up any other apparatus.

Each student is expected to perform the entire experiment by himself unless otherwise directed by the instructor.

Learn to use small quantities of reagents, thereby saving time and expense which working with larger quantities involves.

Each experiment is to be recorded in the laboratory note book immediately after its completion, and records with instruction sheets are to be submitted to the laboratory instructor at the close of each period.

When you have completed the course, or, if you leave before completing it, see that your locker contains a complete clean outfit and place clean paper in the drawer and on the shelf. Have the instructor check your apparatus. He will place a new padlock on your locker and O K your receipt for the coupon book which you deposited with him at the beginning of the course. Next present the O K'd receipt to the custodian of supplies, get the deposited book and return it to the University treasurer for credit or redemption.



## 1. GLASS MANIPULATION

*Keep Your Asbestos Square on the Table and Lay all Hot Glass on the Asbestos*

1. Place a file scratch on a piece of 6 mm. glass rod about  $12\frac{1}{2}$  cm. from the end by pressing sharply on a triangular file with the sharp edge in contact with the glass. A single well-defined scratch is sufficient. With your thumb nails together on the side opposite the scratch and the other fingers around the rod pull toward yourself. A slight pressure will cause the rod to break if the scratch is a sharp one. Next remove the rough edges from the ends of the rod by rubbing on the flat surface of the file and then hold it in the upper part of a Bunsen flame, rotating constantly until the edges of the glass have melted down sufficiently to remove any visible roughness of surface. The object in rounding the ends of glass rods is to prevent the scratching of beakers and flasks in which they may be employed later. Prepare two  $12\frac{1}{2}$  cm., two 15 cm. and two 18 cm. rods.

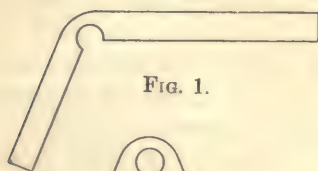


FIG. 1.



FIG. 2.



FIG. 5.

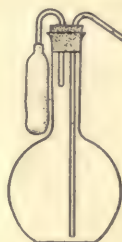


FIG. 6.

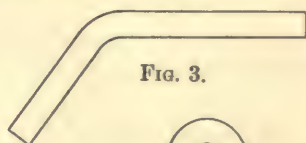


FIG. 3.



FIG. 4.

2. Cut six lengths of glass tubing (5 mm. in diameter and 12 cm. long) and soften one of these at the middle by rotating in an ordinary Bunsen flame. Now bend so that the inner angle is  $90^\circ$  or less. Repeat this experiment, heating the glass in the flame produced by a fish-tail burner. Which of the two methods is preferable and why? By the latter method prepare two angles of  $45^\circ$ , two of  $90^\circ$  and two of  $135^\circ$ . Again file the rough edges and round the ends in the flame. If angles resemble Figs. 1 and 2 they are incorrect; if Figs. 3 and 4 correct.

3. Heat a 12 cm. length of glass tubing at the middle in a Bunsen flame, rotating constantly until soft, and then pull the ends in as nearly a straight line as possible. Examine even the narrowest part of the resulting tube and note whether it is solid or hollow. Now break the tube at the 1 mm. diameter point and slightly melt the edges in the Bunsen flame. How does the glass flow, toward the center or outward? What advantage is this in preparing a smaller opening? Next take a piece of the original glass tubing whose end has been cracked off at right angles to the length of the tube and heat in a flame rotating until only a very small opening is left.

4. Heat a piece of glass tubing until the end is soft and then introduce a pointed piece of charcoal, turning the tube and applying slight pressure. Note that the charcoal does not adhere to the soft glass and that it may be used for shaping glass.



5. Prepare a wash bottle like Figs. 5 or 6, using 5-mm. tubing, a 500 cc. flat bottom flask and a two-hole rubber stopper to fit. The outer end of the long tube should be heated until the opening is of about 1 mm. diameter. If bottle 6 is selected the opening of the outer end of the short tube should be heated and distended slightly to prevent the rubber bulb from slipping off. Bottle 6 is the more sanitary of the two.

*Always moisten glass tubing before introducing it into a rubber stopper. When forcing a tube through a stopper place a cloth over the end which you are pressing, otherwise a serious accident may result.*

**2. PHYSICAL AND CHEMICAL CHANGE. MIXTURE AND COMPOUND**

6. Weigh 5 g. pulverized iron in a porcelain crucible. Rest the crucible on a triangle supported on the ring of an iron stand. Heat gradually and finally strongly for about ten minutes. Do not allow the flame to go beyond the upper edges of the crucible. Have your crucible about 5 cm. above the top of the burner. After the crucible and contents have cooled reweigh same and note the second weight. Is there a material difference between the original weight and that recorded after heating? How do you account for the change which has taken place? Is it a physical or chemical change?

7. Heat a small piece of magnesium ribbon in a Bunsen flame noting the original appearance of the ribbon, the phenomena taking place during the experiment, and the final appearance. Is the change chemical or physical? What form of energy brought about the change and what energy phenomena resulted from it?

8. Carbon disulphide is poisonous and inflammable; therefore, keep it away from a flame and do not inhale any more of the vapors than absolutely necessary. Place some crystals of sulphur in a test-tube and add about 1 or 2 cc. of carbon disulphide. Shake the contents and note whether any change has taken place. Pour a little of the liquid on a watch crystal and allow it to evaporate in the hood at room temperature. On another watch crystal allow a little carbon disulphide to evaporate. Has the sulphur undergone any change?

Place some pulverized iron on a piece of paper and suspend a magnet over it. How does it act? Is this a physical or chemical phenomenon? Also try the effect of the magnet on the sulphur and of carbon disulphide on iron and note results.

Prepare a mixture of 3 g. each of sulphur and iron, first grinding the sulphur in a mortar. After mixing thoroughly suspend a magnet over a little of the mixture and note results. Place the remainder of the original mixture in a hard glass test-tube (these test-tubes have a characteristic green color and are thicker than ordinary test-tubes) and heat in a flame. Observe changes taking place and note same carefully. After cooling, crush the test-tube, pulverize its contents and apply a magnet. In another test-tube heat a little sulphur. It is not necessary to try heating the iron as experiment 6 indicates what would take place. State which of the changes in experiment 8 are chemical and which purely physical. Indicate mixtures and compounds.

9. Place 5 g. common salt in a small porcelain dish and add 15 cc. of water. Evaporate to dryness slowly over a low flame. Taste the salt before putting it into solution and also taste the substance resulting from the evaporation. Do you notice any change? Is this process a physical or chemical one?

10. Heat a piece of iron wire to redness and then allow it to cool. Repeat this same experiment using a splint of wood. State which change is chemical and which physical.

11. To a test-tube containing 20 cc. of water add one drop of dilute hydrochloric acid. Test the solution by dipping a stirring rod into it, shaking off as much of the liquid from the rod as possible, and then touching your tongue with the wet end. Now add a drop or two of sodium bicarbonate solution to the other solution. Taste a little of the sodium bicarbonate solution and then again taste the contents of the test-tube. Note the results. Is this a chemical or a physical change?

12. To a test-tube containing 10 cc. of water add one drop of dilute phenolphthalein solution. Next add a drop of sodium hydroxide or potassium hydroxide. Note results. Is this a physical or chemical change?

13. State which of the following are chemical and which physical changes: Freezing of water; formation of steam; the change of sweet to rancid butter; the molding of bread; the change of color in foliage; the melting of solder; the rusting of iron.

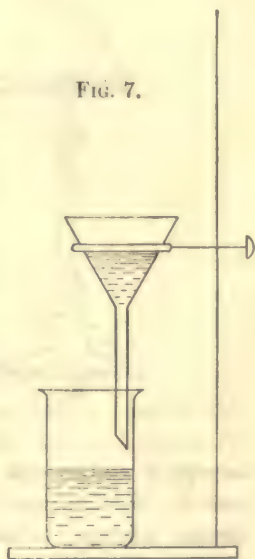




## 3. PURIFICATION OF SUBSTANCES

**14. Filtration.** To 100 cc. water in a 200 cc. beaker add 10 cc.  $\text{CaCl}_2$  (calcium chloride) solution from the general reagent shelf and then 10 cc.  $(\text{NH}_4)_2\text{CO}_3$ , (ammonium carbonate) solution. Warm the solution and filter. (Fig. 7.) To filter fold a  $12\frac{1}{2}$  cm. paper double on its greatest diameter and then refold to obtain  $90^\circ$  angle. Open the filter paper into a cone with one thickness of paper on one side and three on the other. Place it in a 75 cm. funnel point down, fingers pressing on the triple thickness, and moisten with water from your wash bottle. When properly fitted the paper should hold a column of water in the stem of the funnel. If you are unable to obtain this, see your instructor. Let the precipitate (solid) settle. Place a 15 cm. stirring rod against the lip of the beaker and transfer the liquid to the filter paper, disturbing the precipitate as little as possible. Finally transfer this also. *Never* run a liquid higher than  $\frac{1}{4}$  cm. from the upper edge of the filter paper.

FIG. 7.



**15. Crystallization.**—Into a 200 cc. beaker pour 100 cc.  $\text{H}_2\text{O}$  (water) and add 30 g. of  $\text{KClO}_3$  (potassium chlorate). Place the beaker on an asbestos square or iron gauze and heat until a glass rod dipped into the solution shows crystals immediately on being removed. Filter. When the solution has all gone through, cover the receiving beaker with a watch glass and let it stand until cool. Then pour the liquid off into the first beaker and transfer the crystals to a clean porcelain dish, spreading them out to dry. Dry on the hot plate at a temperature not exceeding the boiling point of water. Scrape the crystals off and bottle them, marking the label " $\text{KClO}_3$  (First Crop)." Now take the residue on the filter paper and add it to the solution poured from crop number one. Heat until all crystals are dissolved, evaporate, filter and crystallize as before. These crystals should be preserved as crop number two. In this way a number of crops are obtained of which the first is the best, impurities usually increasing in each of the succeeding ones. To obtain C. P. (chemically pure) materials, the first crop is frequently recrystallized a number of times. Second and third crop crystals are sold as T. P. (technically pure), or commercial chemicals.

**16.** Repeat experiment 15, using 50 g. commercial  $\text{CuSO}_4$  (copper sulphate) in 50 cc. water and prepare only one crop.

**17.** Look up the solubility at  $20^\circ$  and  $100^\circ$  C. of  $\text{NaCl}$  (sodium chloride or common salt),  $\text{CuSO}_4$ ,  $\text{KClO}_3$  and state which can best be purified by cooling a saturated solution; by evaporating a saturated solution. Why?



**18. Sublimation.** Place 5 g.  $\text{NH}_4\text{Cl}$  (ammonium chloride) on a clock glass over an asbestos plate. Cover with a funnel. Heat gently (Fig. 8). What happens? What is this process called? Another example of a substance which may be sublimed is iodine, which yields a purple vapor condensing to dark crystals.

**19. Distillation.** Place hydrant water in 500 cc. flask *A*, Fig. 9. Connect tube *K* which passes into a glass condenser *B* (borrow this at the supply room and return it at the close of the period), through a rubber stopper. A rubber tube from the water cock at your sink is connected with the lower side tube of the condenser. The overflow water is carried to the upper side-tube and

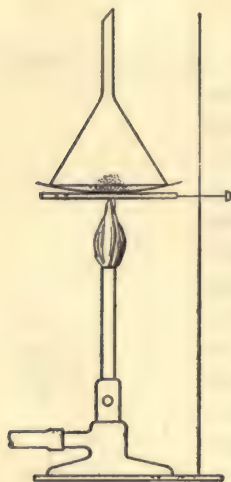


FIG. 8.

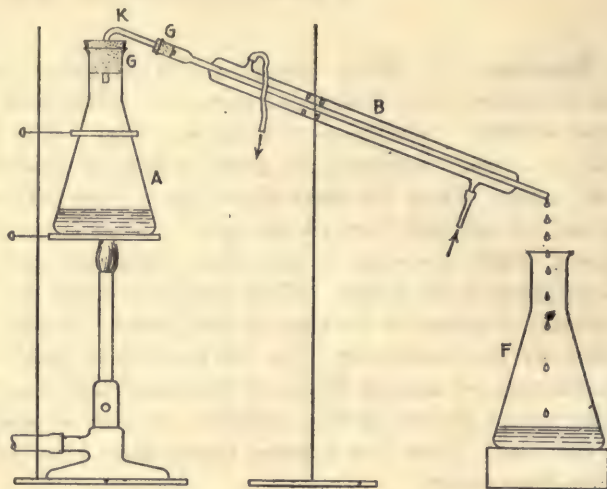


FIG. 9.

through a rubber hose connection to the sink. The distilled water is received in a perfectly clean flask *F*. *G-G* are rubber stoppers. Before starting the distillation add a few crystals of  $\text{CuSO}_4$  (copper sulphate) to the water in *A*. To a test-tube containing a little water add a drop of  $\text{CuSO}_4$  solution and then several drops of  $\text{NH}_4\text{OH}$  (ammonium hydroxide). Note color. This is a test for copper. Apply the same test ( $\text{NH}_4\text{OH}$ ) to the distillate obtained in *F*. Evaporate a few drops of hydrant water to dryness on a clean watch crystal. Note result. Repeat using a few drops of water from flask *F* and note the difference. Does distillation remove all solids? How does it differ from filtration? Does it remove gases?

#### 4. OXYGEN. LAW OF CONSTANT PROPORTION

20. Weigh a hard glass test-tube. Introduce about 1 g. of pure potassium chlorate. Weigh again. The difference is the weight of the potassium chlorate. Fit the tube with a one-hole rubber stopper and delivery tube as shown in illustration. Next fasten the tube to an iron stand, using a burette clamp. Place a stopper in your sink and fill to within two inches of the top. *Do not let the sink overflow.* Place a metal shelf across the sink so that the shelf rests under water. Now fill

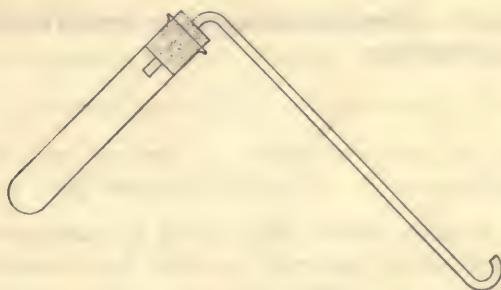


FIG. 10.

several 250 cc. wide-mouth bottles with water, invert them under water and place them over holes on the shelf. Move the iron stand over so that the outlet of the delivery tube is under one of the holes in the trough shelf. Heat the hard glass tube slowly until the contents melt and then *very cautiously* continue heating until gas bubbles cease to come over. With the flame still under the test-tube remove the stopper. *Otherwise water from the trough will be sucked back and spoil the experiment.* After tube has cooled weigh it. Connect up once more, reheat gradually, cool and weigh again.

Weight of tube+potassium chlorate.....	g.
Weight of tube alone.....	g.
Weight of potassium chlorate.....	g.
Weight of the tube+potassium chlorate.....	g.
Weight of same after heating.....	g.
Loss of weight (oxygen).....	g.
Weight of potassium chlorate.....	g.
Weight of oxygen.....	g.
Weight of residue (potassium chloride).....	g.
Volume of oxygen formed.....	cc.
Temperature of room.....	C.
Barometric reading.....	mm.
Per cent of oxygen in potassium chlorate.....	per cent
Per cent of potassium chloride in potassium chlorate.....	per cent
Total.....	per cent



After adjusting the water level inside and outside mark the gas level in each bottle by a gummed label. Next slip a small glass plate over the mouth of the bottle and set it on the table, mouth up. Introduce a glowing splint of wood and note how the gas behaves. Does this convince you that it is different from ordinary air?

Having completed this test, measure the volume of gas obtained by running water into the empty bottles from a graduated cylinder until the labels are reached.

Does potassium chlorate follow the Law of Definite or Constant Proportions? Is it an element, a compound, or a mixture?

**21.** Place a crystal of potassium chlorate in a test-tube. Dissolve in a little water and add a drop of silver nitrate solution (general reagent shelf). Next try the same experiment with a little of the residue obtained by heating potassium chlorate. Record results. Is silver nitrate a test for chlorides or chlorates?

**Notice.** Although the student is asked to compare results with his neighbor in this instance, it is not desirable as a general rule.

## 5. OXYGEN

**22a. Preparation.** Place a little  $\text{KClO}_3$  (potassium chlorate) in a test-tube. Heat slowly, and when the substance boils, lower a glowing splint into the tube, *being careful not to touch the chlorate*. How does the gas differ from air? Write equation for reaction.

**22b.** Next prepare a mixture containing approximately 8 g. finely pulverized  $\text{KClO}_3$  and 4 g.  $\text{MnO}_2$  (manganese dioxide). Place a *little of the mixture* in a test-tube and heat. Introduce a glowing splint as before. Did you notice a difference in the time and heat required?

At what temperature can oxygen be prepared from  $\text{MnO}_2$ ? From  $\text{KClO}_3$ ? From a mixture one-quarter  $\text{MnO}_2$  and three-quarters  $\text{KClO}_3$ ? Define "catalytic agent."

**23.** Place a little  $\text{Na}_2\text{O}_2$  (sodium peroxide) in a test-tube and add a few drops of water.

**Caution.** Do not allow the solid or solution to come in contact with the skin, as they produce painful burns. Test for oxygen as before. Write equation for reaction.

**24.** Now place the remainder of your  $\text{KClO}_3$ - $\text{MnO}_2$  mixture in a test-tube fitted with a one-hole stopper and delivery tube and collect several bottles of oxygen. Into one introduce a little burning sulphur in a deflagration spoon (see illustration). Into another, some iron picture wire tipped with a bit of burning sulphur. Test the solution of the first with blue litmus paper and note results. What does this indicate? Into a third lower a spoon containing charcoal previously heated to redness in a Bunsen flame. Note results. Write equations representing reactions which take place. How does concentration affect the speed of a reaction? Use oxygen and air for comparison.



FIG. 11.

**Warning.** Do not handle phosphorus with the fingers; use metal forceps.

**25.** On a cold iron plate (in hood) place a small piece P (phosphorus), a small distance from this a little S (sulphur) and at a third point some C (charcoal). Place a burner underneath and note the order in which the substances ignite. Define "kindling temperature." Does every substance have a definite kindling temperature? How does temperature affect the speed of reaction?

**26.** Into a test-tube pour 2 or 3 cc.  $\text{KMnO}_4$  (potassium permanganate). Into another pour the same volume of  $\text{H}_2\text{O}_2$  (hydrogen peroxide) and a few drops of dilute  $\text{H}_2\text{SO}_4$  (sulphuric acid). Tear off a small piece of sponge, moisten it, drop it into the dark solution and afterwards into the other. Repeat if necessary. Rinse the sponge in water and compare the color with that of the untreated sponge. Now suspend a piece of moist unbleached sponge in a bottle of oxygen. Compare results.

Define "nascent" oxygen. How does its action differ from that of ordinary oxygen?

Which is the most important laboratory method for the preparation of oxygen? Name the two most important commercial methods. Name the method possessing special advantages for use in medicine and mine rescue work. Which method results in the breaking up of a compound into its elements?





## 6. DETERMINATION OF OXYGEN IN AIR

**Warning.** Sodium hydroxide attacks the skin, so be exceedingly careful in working with it.

27. Apply at the stock room for 10 g. NaOH (sodium hydroxide). Dissolve in 15 cc. water in a small beaker. Cool the solution by setting the beaker in cold water and transfer it to the original test-tube keeping stoppered until ready to use. Also obtain 1 g. of pyrogallol and dissolve in 5 cc. of water in a separate test-tube. Fit combustion tube *B*, Fig. 12, with a one-hole stopper at each end. Each stopper should be fitted with a glass tube which barely extends through the narrow end and protrudes  $\frac{3}{4}$  in. beyond the wide end.

Stoppers are indicated by *C* in the illustration. Over each protruding end slip a 2 in. length of tight-fitting rubber tubing. Close the lower rubber connection by a screw compressor and the upper by a pinch-cock. Fasten the combustion tube to an iron stand in an inclined position, using a burette clamp. At the pinch-cock end connect the tube of a small funnel, *A*. Mix the two solutions, pour the mixture into the funnel, open the pinch-cock and close it again when as much as possible has entered the combustion tube. Now run the solution back and forth in the combustion tube for ten or fifteen minutes, after removing the funnel. Fill your sink with water. Place the pinch-cock end of the tube under water and open the pinch-cock, allowing water to rise in the tube until the level in the tube is equal to the water level in the sink. Now close the pinch-cock and remove the tube from the sink. Next hold the pinch-cock end over a measuring cylinder, open the screw compressor and finally the pinch-cock, measuring the volume of solution. Fill the tube completely with water and insert the stoppers. Run the water into a measuring cylinder and thus determine the total content. Make the following records:

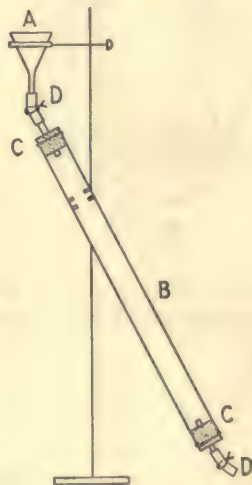


FIG. 12.

(*x*) Original volume of stoppered tube . . . . . cc.

(*y*) Volume of pyrogallol + water (oxygen displaced) . . . . . cc.

$$\frac{y}{x} \times 100 = \text{per cent oxygen by volume.}$$





## 7. OXYGEN AND HYDROGEN. PREPARATION BY ELECTROLYSIS

**Warning.** See that the current is shut off under the sink before making any connections.

28. Students may work in pairs on this experiment so as to avoid the necessity of purchasing two platinum wires. Though working in pairs each student is required to prepare notes. Bend one end on each of two platinum wires around the point of a pencil so as to form a small loop (Fig. 13). Then bend the wires double so that about 1 in. of the straight end is on the inside of each of two test-tubes of uniform diameter. Fasten the wires in place by slipping a small rubber band over the outside of the test-tube at the open end. Fill a 6 in. porcelain dish to within  $\frac{1}{2}$  in. of the top with water containing 10 drops of concentrated  $\text{H}_2\text{SO}_4$  (sulphuric acid). Now pour some of this solution into each of the test-tubes until full, place your thumb over the end of each tube and invert it under the solution in the dish, raising just sufficiently to bring the small platinum loops *above* the surface of the liquid. Fasten the tubes in position by burette clamps which are attached to the rod of an iron stand. Now connect with the direct current using bell wire with an incandescent lamp in series. Keep the copper wires out of the solution as their introduction would cause an error. Turn the current on and allow it to flow until one tube is just filled with gas.

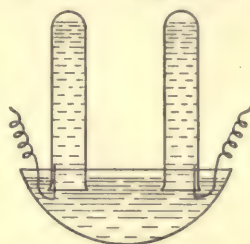


FIG. 13.

Volume of hydrogen formed..... cc.

Volume of oxygen formed..... cc.

What is the proportion of these gases by volume?.....By weight?.....

Introduce a glowing splint into the tube containing oxygen. Try the same experiment with hydrogen but keep the tube inverted. Does hydrogen burn? Does oxygen burn? Does hydrogen support combustion in the ordinary sense? Does oxygen? Why use platinum wires and not copper? Which wire is the anode? Which cathode? At which of these poles does hydrogen escape? Oxygen? Why? What is an ion?





## 8. HYDROGEN

**Warning.** Hydrogen when mixed with air is explosive. Keep your generator covered with a cloth so as to prevent the glass from flying, in case an explosion should occur.

29. Set up the hydrogen generator shown in Fig. 14, using a 125 cc. bottle, a two-hole stopper, a thistle tube (the end of which extends within 5 mm. of the bottom of the bottle), and a delivery tube (the end of which extends just beyond the under side of the stopper). Into the bottle drop

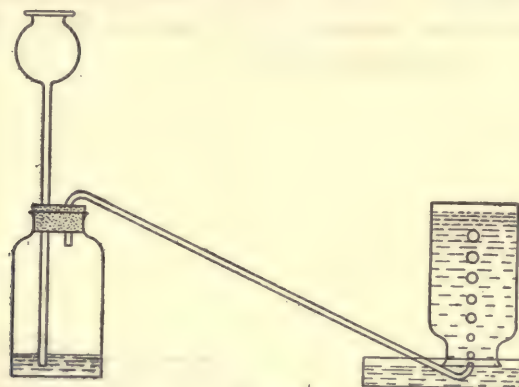


FIG. 14.

several pieces of mossy zinc. Cover it with water to a depth of 10 mm. Add three to five drops of  $\text{CuSO}_4$  (copper sulphate) solution and then after introducing the stopper with the thistle tube whose end rests below the water, add conc.  $\text{H}_2\text{SO}_4$  (sulphuric acid) a drop at a time, until hydrogen begins to form. A little more may be added from time to time as needed. Shake the generator occasionally to keep the solution stirred.

**Warning.** Concentrated sulphuric acid produces painful burns. If any happens to get on the skin wash freely in running water. For subsequent treatment use a solution or paste of sodium bicarbonate. Unless *very slight*, report an accident to your instructor immediately.

**Note.** Concentrated sulphuric acid *should be poured into water slowly*. Never run the water into the acid, as a great amount of heat is generated and an accident may result.

After your hydrogen generator has been in operation several minutes, fill a test-tube with water, invert it in the trough and fill it with gas from the generator. Placing your thumb over the tube bring it near a flame. If a whistling sound or slight explosion results the hydrogen is contaminated with air. Repeat the test until the gas in the test-tube burns quietly. Now collect several bottles of hydrogen in the pneumatic trough by displacement of water.



30. Place an empty bottle in position *B*, Fig. 15. Holding a bottle of hydrogen mouth down, gradually lower the closed end until the bottle reaches position *A*, Fig. 15. See if bottle *B* contains hydrogen, by applying a flame. What does this experiment signify?

31. Into another bottle of hydrogen, mouth down, introduce a glowing splint of wood. Next kindle the splint and introduce into the bottle. Note the appearance of the splint inside the bottle and the phenomenon at the mouth of the bottle. Does hydrogen support combustion? Is it combustible? Compare with oxygen.

32. Procure a small piece of Na (sodium) from your instructor, keeping it in a perfectly dry crucible.

**Warning.** Do not handle Na with the fingers. Keep a safe distance away when experimenting with Na as the metal melts in water and occasionally causes an explosion.

Fill a large beaker two-thirds full with water and add a few drops of phenolphthalein solution (general reagent shelf). Float a piece of filter paper on the water and then drop the Na on the paper. Note three phenomena which indicate that a chemical change has taken place. Write equation representing reaction.

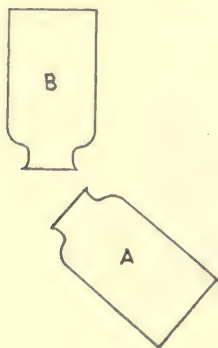


FIG. 15.

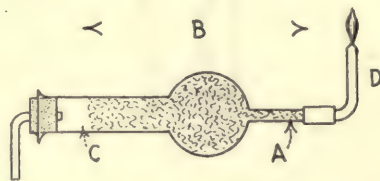


FIG. 16.

33. Drop a small piece of Zn (zinc) into a test-tube; into another a small Fe (iron) wire nail; into a third a small piece of Al (aluminum); into a fourth a small piece of Mg (magnesium). Pour a little dilute  $\text{H}_2\text{SO}_4$  (bottle on *your* reagent shelf) into each tube and note results. Now heat the tubes and note results. Try same experiments, using dilute HCl (hydrochloric acid), and note results. Write equations representing reactions. If pure hydrogen is odorless, which of these methods would you consider objectionable considering this property? Mg and Al are quite expensive, Zn and Fe are cheap. Which of the four do you consider best for the economic preparation of the pure gas in the laboratory?

34. Remove the delivery tube from your hydrogen generator and substitute the drying tube shown in Fig. 16. This consists of a right-angle tube fitted into a rubber stopper at the wide end of the drying tube. A loose tuft of cotton is placed at the small end (*A*) of the drying tube, the  $\text{CaCl}_2$  (calcium chloride) is introduced (*B*), and again a loose tuft of cotton at the wide end (*C*). To the small end of the drying tube attach a small glass tube bent upwards (*D*), having a minute opening about the size of a pin point. When certain that the hydrogen is free from air, light the gas at *D* and suspend a funnel over the flame. What forms? Why use the  $\text{CaCl}_2$  tube? Afterwards slip a rubber tube over each end and fit it with a plug made of glass rod so as to prevent absorption of water and preserve the drying tube for future use.

35. Into a clay pipe introduce a solid rubber stopper, or a perforated one in which the holes are plugged by glass rods. To the stem attach a piece of rubber tubing. Let the tubing dip under water in a beaker, Fig. 17, and lower a beaker of hydrogen over the pipe. What happens? Give formula for the rate of diffusion of gases. From this calculate the relative rates of diffusion of  $H_2$  and  $O_2$ .

36. Calculate the volume of hydrogen,  $20^\circ$  and 730 mm., obtainable from 5 g. Fe; from 5 g. Zn; by treatment with  $H_2SO_4$ .

37. Place some soap solution in a small porcelain dish. Pass air through from the compressed air line until a lather has been formed. Then pass a little hydrogen through the solution. Remove the delivery tube a safe distance. Throw a cloth over your hydrogen generator. Hold a lighted splint over the soap solution *keeping at a safe distance*. Note results.

38. How much heat is evolved when two grams of hydrogen are converted into steam? Into water?

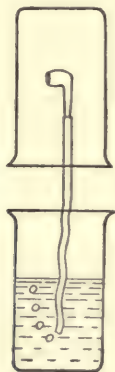


FIG. 17.

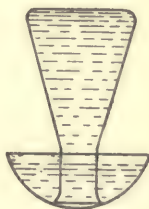


FIG. 18.

39. Weigh accurately about 0.2 g. magnesium ribbon and place it under a 500 cc. flask filled with very dilute HCl (hydrochloric acid) and invert in a large porcelain dish containing water. The mouth of the flask should rest on the bottom of the dish (see Fig. 18). When all the Mg has dissolved lower the dish and flask in a sink filled with water and mark the place where the liquid inside and outside the flask reaches the same level. Determine the volume of hydrogen liberated. Note the room temperature and barometric pressure, and correct to standard conditions. Then calculate the weight of the hydrogen. The atomic weight of magnesium is 24. What is its valence on the basis of this experiment?

40. (a) Calculate the volume of hydrogen and oxygen, measured at  $20^\circ$  under 740 mm. pressure which will result from the electrolysis of 36 g. of water.

(b) Calculate volume of oxygen obtained from potassium chlorate in a previous experiment, correcting for temperature and pressure.





## 9. COMPOSITION OF WATER

41. Students may work in pairs on this experiment, one constructing the apparatus while the other weighs the porcelain boat and  $\text{CuO}$  (copper oxide) and tube *E*. Each student will submit a report on the entire experiment.

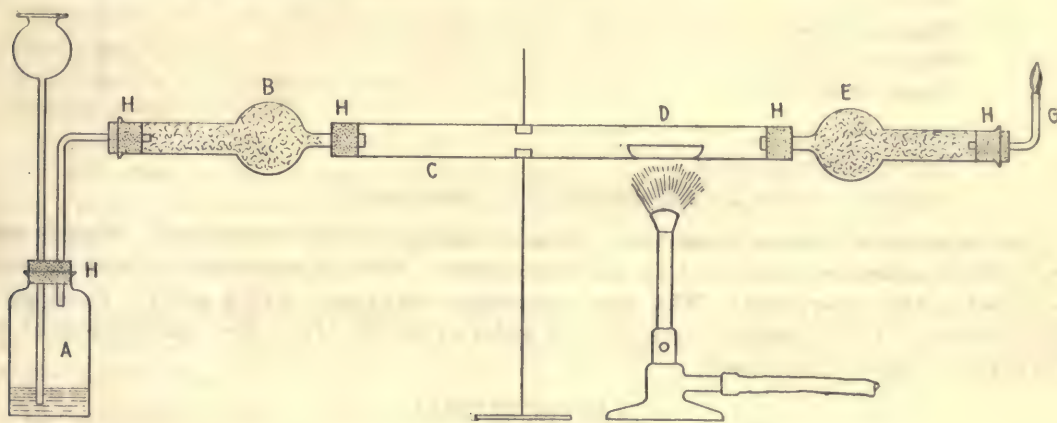


FIG. 19.

Prepare apparatus according to illustration; *A*, a hydrogen generator as previously prepared in experiment 20, introducing enough zinc to cover the bottom of the bottle; *B* and *E*, drying tubes as previously prepared in experiment 35. When not in use, small plugs, made of glass rod, should be slipped into the rubber connections and stoppers of drying tubes so as to prevent absorption of moisture from the air. Keep the tubes for future experiments. *C*, combustion tube; *D*, small porcelain boat; *G*, small tube almost closed at outlet to burn escaping hydrogen; *H*, rubber stoppers. Clean and dry your porcelain boat, warming in flame to drive out moisture. Weigh it accurately to milligrams. Introduce about 2 grams  $\text{CuO}$  (black oxide of copper, also known as cupric oxide). Weigh accurately again. Place the boat with contents in the combustion tube *C*. Weigh tube *E* and contents, removing tube *G* and inserting a small piece of glass rod into the rubber stopper to prevent absorption of moisture from the air. Be careful to insert the same plugs for later weighings. Start the hydrogen generator, testing for air by inverting a test-tube over *G*, placing your thumb over the tube and later igniting the contents. Before doing this it is well to see that all rubber connections (stoppers and tubing) are perfect. When the hydrogen in the test-tube ceases to whistle or explode cover your generator with a cloth and light the hydrogen at *G*. Then fit a Bunsen burner with a fishtail tip and wave the flame gently back and forth until the combustion tube heats up, finally letting the flame play constantly on the tube below the boat, until the entire contents have turned red. It is well to incline the tube *C* slightly downward toward *E* so that water formed will run in that direction. This may all be forced into *E* by gradually working the flame toward the right. Less difficulty will be experienced if the boat is placed nearer the right of the tube. After reduction is complete, remove the flame and allow the apparatus to cool, still continuing the stream of hydrogen. When cool weigh the porcelain boat and contents and also the tube *E*.



Weight of tube <i>E</i> after reduction.....	g.
Weight of tube <i>E</i> before reduction.....	g.
Weight of water formed.....	g.
Weight of boat+CuO.....	g.
Weight of empty boat.....	g.
Weight of CuO.....	g.
Weight of boat+Cu.....	g.
Weight of empty boat.....	g.
Weight of Cu.....	g.
Weight of CuO.....	g.
Weight of Cu.....	g.
Weight of O <sub>2</sub> .....	g.
Weight of H <sub>2</sub> O.....	g.
Weight of O <sub>2</sub> .....	g.
Weight of H <sub>2</sub> .....	g.

Ratio of H<sub>2</sub> to O<sub>2</sub>.

Atomic weight of O = 16.

Formula for water derived through above experiment.

State the Law of Definite Proportion. How is it verified by this experiment? What is **reduction**? Which substance is reduced in this experiment? What is **oxidation**? Which substance is oxidized in this experiment? Why does a substance serve as a drying agent? Compare the vapor pressure of CaCl<sub>2</sub> (calcium chloride) and water at 30° C. How does this experiment illustrate both analysis and synthesis?

### 9A. PROBLEMS\*

Show all calculations on the unruled side of your report paper. Carry calculations to three decimal places.

1. Calculate the weight of each reaction product which will result on heating 10 g. potassium chlorate. As one liter of oxygen weighs 1.429 g. under standard conditions (0° C. under 760 mm. pressure) calculate the volume of oxygen obtained. What will its volume be at 23° C. under 740 mm. pressure? At 10° below zero centigrade under 780 mm. pressure. At 273° A. under 710 mm. pressure? Atomic weights: K=39.1, Cl=35.46 and O=16.

2. Calculate the weight of each reaction product when water acts on 10 g. sodium peroxide; also the weight of water required; also the volume occupied by the resulting gas at 20° under 735 mm. pressure. Atomic weights: Na=23, H=1.008, O=16.

3. Calculate the weight of each reacting substance in the preparation of 100 liters of hydrogen, measured at 273° C. under 1520 mm. pressure, from aluminum and hydrochloric acid. One liter of hydrogen under standard conditions (0° C. and 760 mm. pressure) weighs 0.08987 g. What volume of hydrogen under standard conditions would be liberated from the same weight of aluminum by sulphuric acid? From weight of hydrogen liberated by one atomic weight of aluminium in grams, calculate the equivalent weight of aluminium. Atomic weights: Al=27.1, H=1.008, Cl=35.46.

4. Calculate the weight of sulphuric acid (acting on zinc) which will produce enough hydrogen to reduce 50 g. copper oxide to copper. How much water will form? Atomic weights: H=1.008, S=32.06, O=16, Zn=65.37, Cu=63.57.

\* Sets of problems not numbered consecutively with regular experiments are intended for use when the student does not require the full time scheduled for assigned experiments.

## 10. WATER

Recall at this point the action of metals on water, i.e., Na, K, etc.; methods of purification, i.e., filtration, distillation, freezing, etc.; the variation of solubility of substances with temperature, etc.

**42. Solubility of Solids in Water.** You already know that substances like NaCl,  $\text{KClO}_3$ ,  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$  (sugar), etc., are soluble in water. Introduce a very small quantity of plaster of paris ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) into a tube containing water and heat to boiling; repeat using marble ( $\text{CaCO}_3$ ). Note results. Are all solid substances soluble in water?

Evaporate five drops of city water on a watch glass and note residue. To what is this due? Repeat using distilled water. Why is no residue observed in this case? If distilled water has been standing in a closed glass vessel for some time and a residue formed on evaporation to what conclusion would you come?

To a solution of NaCl in water add a few drops of  $\text{AgNO}_3$  (silver nitrate) solution and note results with equation for reaction. Boil and examine again. What term is applied to the separation of a solid from solution in this way? Does temperature affect the form of the separated material? Expose the tube to daylight for some time and note result. Light evidently brings about chemical changes in some cases.

**43. Solubility of Liquids in Water.** Place a few drops of alcohol in a little water in a test-tube, shake and note that it has dissolved; repeat using glycerine instead of alcohol. Into a third tube containing water pour a few drops of oil and shake. Note results. Are all liquids soluble in water?

**44. Solubility of Gases in Water.** Fill a test-tube completely with city water, invert it over water in a dish, clamp the tube in position and warm from above by playing a Bunsen flame on the walls of the tube. Note results and account for same. How can you remove gases which are dissolved in water?

Examine the table of solubilities on the inside front cover of your text book (Alexander Smith, General Chemistry for Colleges).

**45a. Water of Hydration.** In separate dry test-tubes, gently heat crystals of copper sulphate, barium chloride and gypsum; also try effect on slaked lime. All substances were apparently dry. Note results and account for same.

Place a few small crystals of copper sulphate in a hard glass test-tube and heat gradually until no further change is perceptible. What has taken place? After the tube has cooled add a drop or two of water and note the change. Give term applied when a substance loses water of crystallization on exposure to the air.

**45b. Water in Food Products.** Gently heat some cracker crumbs in a test-tube; repeat, using corn grains. Note results and account for same. Similar results would be obtained with meat, bread, fruits, potatoes, etc. What does this experiment indicate?

**46. Absorption of Water.** Place a few small pieces of  $\text{CaCl}_2$  (calcium chloride) in a perfectly dry test-tube and allow it to stand for several hours. Note results. What is this phenomenon called?

Other substances absorb water and since, like  $\text{CaCl}_2$ , they have low vapor pressures they serve as drying agents. Among the best agents are  $\text{P}_2\text{O}_5$ , CaO,  $\text{H}_2\text{SO}_4$ . Some like  $\text{P}_2\text{O}_5$  and CaO combine with water to form new compounds.

Define saturated solution; supersaturated solution; supercooled liquid; water of hydration; water of crystallization; deliquescence; efflorescence; precipitate.





## 11. WATER IN HYDRATED BARIUM CHLORIDE

47. Clean a porcelain crucible and lid, wipe dry with a cloth and place on a pipe-stem triangle supported by the ring of an iron stand. Heat gently at first, then gradually to redness. Cool and weigh the crucible and cover accurately. Introduce about 2 g. of C.P. (chemically pure)  $\text{BaCl}_2 \cdot \times \text{H}_2\text{O}$  (crystallized barium chloride of which you do not know the water content). Again weigh accurately. You will find small bottles of barium chloride on the balance shelf. Remove the quantity you need and *carefully recork* the bottle.

Once again place the crucible (covered) and contents on the triangle, heat gently at first, and gradually to dull red heat, leaving it at the latter temperature for about ten minutes. Cool and weigh quickly. Repeat the heating and weigh again. Heating must be repeated until there is no further change in weight.

Weight of crucible + $\text{BaCl}_2 \cdot \times \text{H}_2\text{O}$ .....	g.
Weight of empty crucible .....	g.
Weight of $\text{BaCl}_2 \cdot \times \text{H}_2\text{O}$ .....	g.
Weight of crucible + dry $\text{BaCl}_2$ .....	g.
Weight of empty crucible .....	g.
Weight of dry $\text{BaCl}_2$ .....	g.
Weight of $\text{BaCl}_2 \cdot \times \text{H}_2\text{O}$ .....	g.
Weight of dry $\text{BaCl}_2$ .....	g.
Weight of $\text{H}_2\text{O}$ .....	g.

$$\frac{\text{Weight of H}_2\text{O}}{\text{Weight of original salt}} \times 100 = \text{per cent of water of crystallization.}$$

Using 137.37 for the atomic weight of barium, 35.46 for chlorine, 1.008 for hydrogen and 16 for oxygen, derive the formula for the  $\text{BaCl}_2$  with its water of crystallization. It is intended that the student shall determine only the number of molecules of water to be added to the formula  $\text{BaCl}_2$ .

This experiment illustrates certain cases of hydrated substances containing fixed quantities of water of crystallization. In some cases a number of molecules are lost at one temperature and the remainder at another or others. Look up data for  $\text{CuSO}_4$ .

How can you distinguish between water of crystallization and absorbed water? Suggest another method for determining  $\text{H}_2\text{O}$  in hydrated barium chloride.

## 11A. PROBLEMS

1. When 2 volumes of hydrogen and 1 volume of oxygen are exploded 2 volumes of steam form. Calculate the volume of steam obtainable by the explosion of gases resulting from the electrolysis of 10 g. water.  $\text{H} = 1.008$ ,  $\text{O} = 16$ .

2. If the steam formed in the above experiment is passed over red-hot pulverized copper, how much  $\text{CuO}$  will be produced?  $\text{Cu} = 63.57$ .

3. Hydrogen is stored in a vessel over water at  $25^\circ$ . The barometer reads 730 mm. Calculate the pressure of the hydrogen.



4. Prepare a graph illustrating the application of Charles' Law showing how the volume changes with temperature and that no gas can exist at the absolute zero.

5. The percentage saturation reading on a "Hygrodeick" for  $70^{\circ}\text{F}$ . is 60 per cent. Calculate the partial pressure of the dry air and water vapor in any volume of this pair if the barometer reads 740 mm.

6. Calculate the per cent of water of hydration in crystals of copper sulphate; potash alum; zinc sulphate.  $\text{Cu}=63.57$ ,  $\text{K}=39.1$ ,  $\text{S}=32.06$ ,  $\text{Al}=27.1$ ,  $\text{Zn}=65.37$ .

7.  $\text{P}_2\text{O}_5$  (phosphorus pentoxide) combines with water to form  $\text{H}_3\text{PO}_4$  (phosphoric acid). Calculate the quantity of the latter obtainable from a gram-molecular weight of the former.  $\text{H}=1.008$ ,  $\text{P}=31.04$ ,  $\text{O}=16$ .

8.  $\text{CaO}$  (calcium oxide) combines with water to form  $\text{Ca}(\text{OH})_2$  (calcium hydroxide). How much of the former is necessary for the preparation of 10 g. of the latter.  $\text{Ca}=40.07$ .

9. 6.15 g. hydrated copper sulphate when heated loses water and only 3.93 g. of anhydrous copper sulphate remain. Assuming the latter to be  $\text{CuSO}_4$ , calculate the formula for the former.  $\text{Cu}=63.57$ .

10. An evacuated vessel of 500 cc. capacity weighs 72.329 g. Hydrogen placed in the vessel at  $20^{\circ}\text{C}$ . under 750 mm. pressure increases its weight to 72.370025 g. Calculate the weight of a liter under standard conditions. Also the density compared with air. What would the flask weigh if filled with oxygen under the original temperature and pressure conditions?

## 12. OSMOTIC PRESSURE

48. Cut a circular sheet of parchment paper slightly larger than the large end of your thistle tube. Borrow a second thistle tube at the supply room and cut a parchment disk to fit this also. *Return the borrowed tube at the close of the period.* Now dip the ends of the thistle tubes into molten sealing wax and immediately bring them in contact with the parchment paper disks. If the wax seals are imperfect close open spaces by touching with a hot rod or file.

Into one tube introduce a molar  $\text{CuSO}_4$  (copper sulphate) solution, just to the narrow tube. Into the other, a molar solution of sugar. This may be accomplished by introducing the long narrow tubes of the pipettes found in the reagent bottles. Immerse both tubes in beakers of distilled water having the water level the same as that of the solution inside the tube. Note the time at which the experiment was begun and the height of the liquids at intervals of half an hour, recording four or five readings if possible. How do the two solutions compare? Why? When will the solution in the tube stop rising? Supposing the membranes equal and perfect, how should the final volume in the  $\text{CuSO}_4$  tube compare with that in the sugar tube?

Define osmosis; osmotic pressure (or suction); solution pressure. Compare relative results observed with effects of similar solutions on the boiling and freezing point of water. Of what use are these phenomena in chemistry? How do these phenomena compare with those observed in gases?

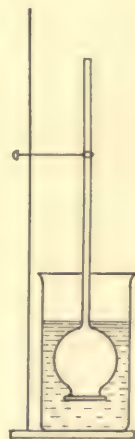


FIG. 20.





## 13. HYDROGEN CHLORIDE

**49. Preparation.** Place 50 g. common salt in a 500 cc. Erlenmeyer flask *A* and then add 20 cc. water and 50 cc. conc.  $\text{H}_2\text{SO}_4$  through a thistle tube which should extend almost to the bottom. Let the reaction proceed in the cold until effervescence ceases and then place a *very small* flame under *A*, which should rest on an asbestos square. Bottle *B* is a safety bottle. Note the arrangement of the tubes. Why? *C* is a 150 cc. Erlenmeyer flask containing 100 cc. water. Continue heating until all action in *A* ceases, *but do not use a large flame*, as this would cause some of the  $\text{H}_2\text{SO}_4$  to vaporize and contaminate the  $\text{HCl}$ . Remove the small flask containing  $\text{HCl}$  and then turn the gas off. Stopper flasks *C* and *A* and preserve both for future use.

**50.** Clean and dry a narrow test-tube. Place a label about one-third from the top and fit the tube with a cork. Fasten a wire around the neck with a small projecting loop so that you may suspend the tube from the hook on a balance and weigh. Next fill the tube with *distilled water* so that the lower part of the meniscus is just tangent to the upper edge of the label. Weigh again. Remove the water, dry the tube and introduce the  $\text{HCl}$  solution you prepared, again with the meniscus tangent to the upper edge of the label. Weigh.

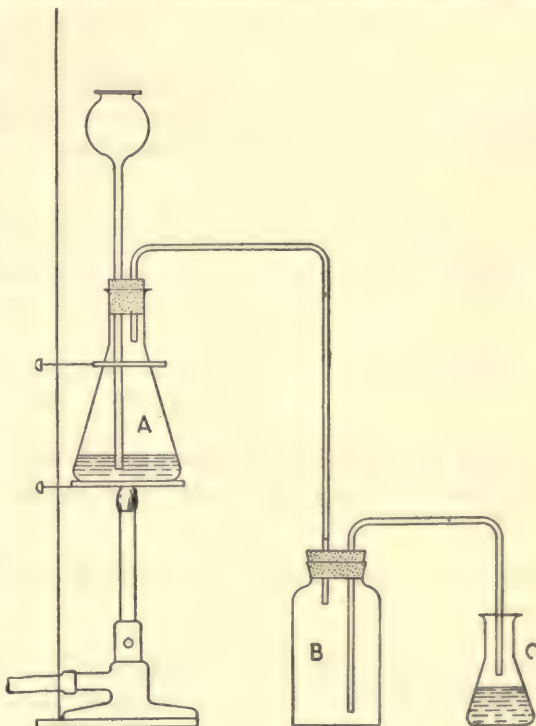


FIG. 21.

Weight of the test-tube+ $\text{HCl}$ solution.....	g.
Weight of empty tube.....	g.
Weight of $\text{HCl}$ solution.....	g.
Weight of test-tube+water.....	g.
Weight of empty tube.....	g.
Weight of water.....	g.

$$\frac{\text{Weight of HCl solution g.}}{\text{Weight of water g.}} = \text{specific gravity of the acid.}$$

**51.** Calculate the volume which the  $\text{HCl}$  expelled from 100 cc. of your acid would occupy at  $20^\circ \text{C}$ . under 740 mm. pressure, assuming that all the  $\text{HCl}$  might be liberated. Is this actually the case? What does happen?





**14. HYDROCHLORIC ACID; ACID, BASE, SALT**

**52.** Try the action of the HCl which you prepared on a small quantity of each of the following metals placed in test-tubes; Fe (iron), Zn (zinc), Cu (copper), Al (aluminium), Mg (magnesium). If no reaction takes place in the cold solution, heat slowly. Note results and write equations representing the reactions which take place.

**53.** Try the action of HCl on the following oxides:— $\text{Fe}_2\text{O}_3$  (ferric oxide),  $\text{ZnO}$  (zinc oxide),  $\text{CuO}$  (cupric oxide),  $\text{Al}_2\text{O}_3$  (aluminium oxide),  $\text{MgO}$  (magnesium oxide),  $\text{CaO}$  (calcium oxide), applying heat if solution fails to take place in the cold. Note results and write equations representing reactions.

**54.** Add 1 drop of HCl to 10 cc. water in a test-tube. Try the effect on blue litmus paper. Taste the solution by dipping a clean stirring rod into the test-tube, shaking the rod to remove as much of the adhering acid as possible, and then bringing it in contact with the tongue. Define acid.

**55.** Add a drop of NaOH (sodium hydroxide) to 10 cc. water in a test-tube. Try the action on red litmus paper. Taste the solution as directed in 55. Define base.

**56.** Take 5 cc. of the solution prepared in 54 and add the solution prepared in 55 a drop at a time until the red litmus just turns color. Taste the solution. Write ionic equation representing the reaction which took place. Define salt.

Summarize the three methods employed for the preparation of a salt and repeat one equation illustrating each method.

**57.** Test for the Cl ion in HCl and in NaCl by adding a drop or two of  $\text{AgNO}_3$  (silver nitrate) solution in the presence of a few drops of  $\text{HNO}_3$ . Heat the solution. Try the effect of  $\text{AgNO}_3$  on a solution of pure  $\text{KClO}_3$ . Why is this not precipitated?





## 15. IONIZATION—ELECTROLYTES—NON-ELECTROLYTES

**58.** To some water in a beaker, add a few drops of HCl. Pour the solution into a U tube and into the ends introduce wires connected with the direct current terminals, having a 60-watt carbon lamp in series. Turn current on. Note results. Remove contents of U tube, rinse it thoroughly with water and then fill with distilled water repeating the experiment. Now dissolve a little sugar in the water and try again. Clean the tube once more and introduce water containing a little NaOH. Try the conductivity. Clean the tube again and introduce water containing a little NaCl. Insert the wires once more. Now clean thoroughly and introduce alcohol. Be sure to have the tube and wires perfectly clean so that the alcohol may be returned to the reagent bottle. Which of these solutions ionize? Write their ionic formulas. Which of the solutions are electrolytes? Which non-electrolytes? How does the number of individual particles in ionized electrolytes compare with that in non-electrolytes? What difference is there in the effect on the depression of the freezing point by electrolytes and non-electrolytes? Advance a simple explanation.

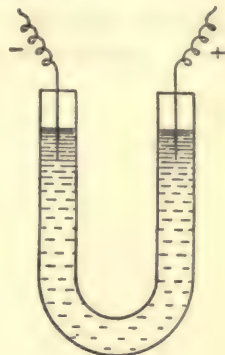


FIG. 22.

**59.** Into a U tube introduce a dilute solution of  $\text{Na}_2\text{SO}_4$  (sodium sulphate) to which enough litmus solution has been added to produce a deep blue color. Introduce the wires and electrolyze. Note results and explain the changes which have taken place. Write ionic equations representing the reactions which take place.





## 16. CHLORINE

**Warning.** This gas irritates the mucous membrane and produces effects resembling a cold. *It is poisonous.* Perform all chlorine experiments, except where chlorine water is used, *in the hood.*

**Antidotes.** Inhale alcohol poured on a cloth, or dilute ammonium hydroxide. If your nose and throat are very sore, spray with liquid vaseline. (Ask custodian of supplies.)

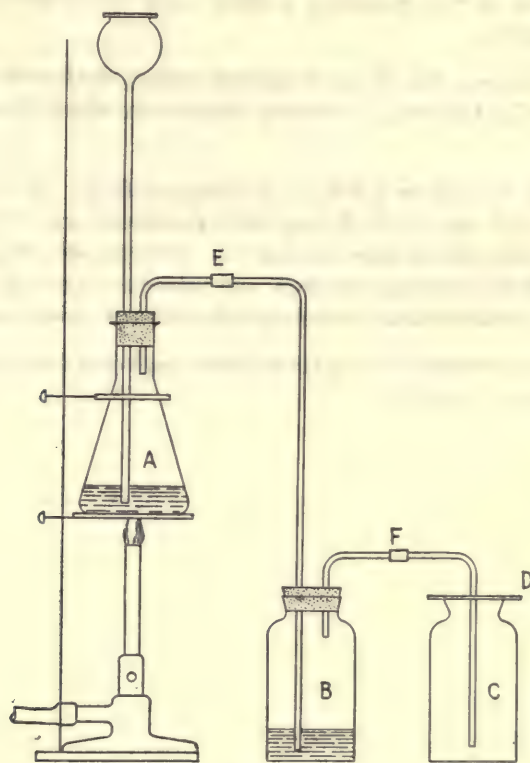


FIG. 23.

60. Prepare the generator shown in Fig. 23 introducing about 50 g.  $\text{MnO}_2$  into the 500 cc. Erlenmeyer flask A, which rests on an asbestos square. Through the thistle tube introduce 20 cc. conc.  $\text{HCl}$ , diluted with an equal amount of water. Warm gradually so that the gas does not generate too rapidly and cause the flask to burst. Into bottle B introduce about 25 cc.  $\text{H}_2\text{O}$  and have the inlet tube dipping just under the water. Collect the chlorine in five bottles (C) and cover these with glass plates D, greased with vaseline, leaving the bottles in the hood until you are ready to perform the experiments for which they are required. It is best to perform the experiments in the hood also. Make a very short rubber connection at E and use about a foot of rubber tubing at F, so that you may lift the delivery tube out of the bottle C without disturbing the rest of the appa-



ratus. After you have collected five bottles of the gas lower the delivery tube into the vent pipe at the side of the hood and let the generator run until chlorine ceases to be evolved. Then disconnect at *E* and remove the burner. Preserve the bottle of chlorine water for future experiments, keeping it in a dark place and *well stoppered*. *Keep hood windows down as low as possible* except when it is absolutely necessary to raise them. You can tell when the bottles are filled by placing a sheet of white paper back of them. The entire contents should appear yellow.

**61.** Into one bottle of  $\text{Cl}_2$  introduce a small piece of filter paper moistened with a few drops of warm spirits of turpentine ( $\text{C}_{10}\text{H}_{16}$ ) and note results. How do you account for the reactions? Write the equation which you think explains the reaction.

**62.** Into another bottle of  $\text{Cl}_2$  drop a little pulverized Sb (antimony). Note results and write equation representing the reaction. Repeat using cold pulverized Fe. Heat a little Fe and try again. Note results and write equation representing the reaction.

**63.** Into another bottle of  $\text{Cl}_2$  introduce a little very thin copper foil previously warmed. Note results and write equation.

**64.** Into another introduce a bit of moist colored cotton cloth and note results. Mention a number of articles which  $\text{Cl}_2$  bleaches. Mention some with which the use of this substance is objectionable.

**65.** Place 5 g.  $\text{KMnO}_4$  crystals in a 500 cc. Erlenmeyer flask. Fit a one-hole rubber stopper with an outlet tube and attach one of the drying tubes prepared some weeks ago. To this connect the delivery tube by the long rubber tube used in 61. Dry one of your bottles perfectly. Then pour a little conc.  $\text{HCl}$  into the Erlenmeyer flask and introduce a small piece of dry colored cloth into the bottle. Compare results with those obtained in 65. Is water necessary for the reaction?

Describe briefly the commercial electrolytic method employed for the manufacture of chlorine, writing equations for reactions involved.

## 17. ACIDITY OF VINEGAR

66. Draw some vinegar up into a 5 cc. pipette by sucking on the open end and allowing the solution to rise above the mark. Quickly place your index finger over the upper end and then release the pressure slightly, permitting the vinegar to drop slowly until the meniscus is tangent to the mark. Again press firmly on the upper end and transfer the contents of the pipette to a perfectly clean 250 cc. Erlenmeyer flask. Draw another 5 cc. from the same sample bottle and run it into a second flask. Note the number of the vinegar you are using.

Dilute the vinegar in each flask with 100 cc. of distilled water, add several drops of phenolphthalein, take the flasks to the titration shelf, note burette reading with meniscus tangent to a mark, and introduce N/5 (fifth normal) NaOH slowly until a pink color appears. Again note the burette reading. Titrate the second portion. As the specific gravity of the vinegar is very nearly one you may call the sample 5 grams. If the two titrations do not agree take a third portion of vinegar and titrate again. The two parallel results should be taken as final.

Calculate the weight of NaOH in the volume of standard solution used and from this the  $\text{HC}_2\text{H}_3\text{O}_2$  (acetic acid). Dividing the latter by 5 grams (weight of vinegar used) and multiplying by 100 will give the per cent of acetic acid in vinegar. Note the kind of vinegar examined as well as its number.

Define normal solution; molar solution.





## 18. CHEMICAL EQUILIBRIUM, SPEED OF REACTIONS, ETC.

67. Write the equation for the reaction taking place in the preparation of HCl from NaCl and H<sub>2</sub>SO<sub>4</sub> at room temperature, indicating the direction which the reaction takes by an arrow instead of using an = sign. Indicate a gas by an arrow pointing upwards.

Into a test-tube introduce a small quantity of saturated NaHSO<sub>4</sub> solution. Add an equal volume of concentrated HCl. Note results and again write the equation given above but change the direction of the arrows as may be necessary. Indicate a precipitate by an arrow pointing downward. Explain fully what has happened.

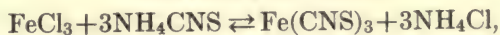
## THE EQUILIBRIUM CONSTANT FORMULA

Suppose that we have two substances A and B reacting to form two new substances M and N and that the reaction is reversible. Then the equation may be written  $A + B \rightleftharpoons M + N$ . Let C represent the *molar concentration* of each, i.e., the number of *molar or molecular weights* in grams per liter when equilibrium is reached. Then the equilibrium constant formula reads:

$$\frac{C_M \times C_N}{C_A \times C_B} = K,$$

where K has a definite numerical value for each temperature. If the concentration C of any of the reacting substances A, B, M or N is changed, that of the others must also change as the numerical value for K is fixed for that temperature.

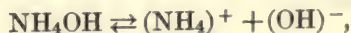
Where more than one mole of a substance is used in a reaction, A, B, M or N is raised to that power expressed by the coefficient. For example:



therefore

$$\frac{C_M \times C_N^3}{C_A \times C_B^3} = K.$$

The same formula holds good for a substance which ionizes. Example:



therefore

$$\frac{C_M \times C_N}{C_A} = K.$$

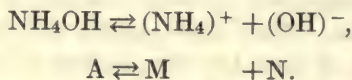


It is evident from these examples that any change in the molar concentration  $C$  of substances  $A$ ,  $B$ ,  $M$  or  $N$  must result in a change for the value of the others since the value of  $K$  cannot change for a given temperature.

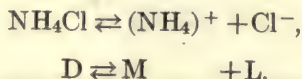
In a sense the value of  $M$  and  $N$ , where a substance ionizes, might warrant our looking upon them as molecules since the same principle is applied in calculations. Here, however, the formula is called the *ion product constant formula*.

**68.** Into each of three 300 cc. beakers introduce 200 cc. distilled water, 20 cc.  $N/100$   $NH_4(CNS)$  (ammonium thiocyanate) and 20 cc.  $N/100$   $FeCl_3$  (ferric chloride). Stir the solutions. To one add 10 cc. of a saturated solution of  $NH_4(CNS)$ . To the second add 10 cc. of a saturated solution of  $NH_4Cl$  (ammonium chloride). Compare these with the third beaker containing the original solution. Note the results and explain them on the basis of the equilibrium constant formula, not using numbers but simply indicating how  $C_A$ ,  $C_B$ ,  $C_M$ , and  $C_N$  change relatively so as to leave  $K$  constant. Solutions of proper strength are ready for use.

**69.** Into a 200 cc. beaker introduce 100 cc. distilled water, add *one* drop of concentrated  $NH_4OH$  and a drop or two of phenolphthalein solution. The latter merely serves as an indicator, turning pink in presence of sufficient  $(OH)^-$



Now add 5 cc. of a saturated solution of  $NH_4Cl$  and note results.



Explain the results on the basis of the *ion product constant formula*, simply indicating changes in values of  $C_A$ ,  $C_M$  and  $C_N$ .

### SPEED OF REACTION

**70. Influence of State of Division of Substance.** Into three test-tubes introduce a piece of zinc, some granulated zinc, and some pulverized zinc respectively. Add 5 cc. of water to each tube and *two* drops of concentrated  $HCl$ . Note results and account for same.

**71. Influence of Temperature.** Heat each of the tubes and note any change in the speed of the reaction. Account for same.

**72. Influence of Concentration.** Add 5 drops more of concentrated  $HCl$  to each test-tube and note results accounting for same.

## 19. BROMINE

**Warning.** Bromine vapor irritates the mucous membrane and is poisonous. The liquid produces painful burns which are difficult to heal.

**Antidote.** Inhale alcohol or apply locally as the case requires.

**73.** Into a small retort *A*, Fig. 24, introduce a mixture of 2 g. pulverized KBr (potassium bromide) 2g.  $\text{MnO}_2$  and 5 cc.  $\text{H}_2\text{SO}_4$  previously diluted with an equal volume of water. *Pour the  $\text{H}_2\text{SO}_4$  into the water.* Heat with a *very small* flame and drive the bromine over into a test-tube half filled with water, having the surface of the water extend above the outlet of the retort. Perform this experiment in the hood and continue heating with a small flame until brown vapors no longer appear in the retort. Write equations representing reactions which take place.

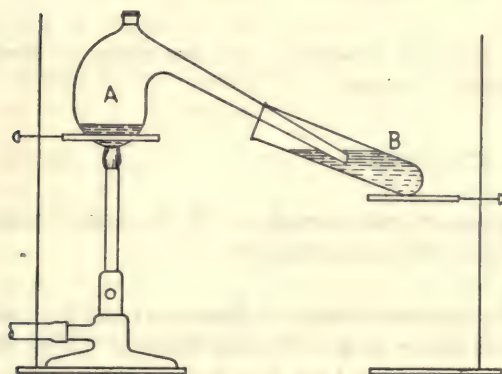


FIG. 24.

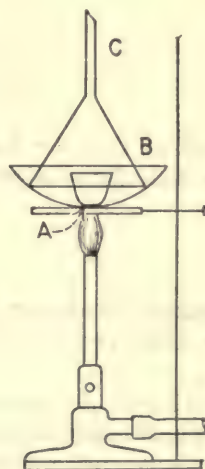


FIG. 25.

**74.** Place a little of the solution in a test-tube and add NaOH (sodium hydroxide) solution a drop at a time until the yellow color disappears. What forms? Write equations for reactions.

**75.** To a little water containing a few drops of KBr solution add several drops of chlorine water. Explain the change and write equations for reactions.

**Note.** The behavior of bromine towards Sb, Cu,  $\text{P}_4$ , Na, etc., is similar to that of chlorine, so it is not necessary to repeat the experiments performed with that element. Write equations explaining reactions of  $\text{Br}_2$  with Sb, Na and  $\text{P}_4$ . How does the last compound act with water? Write equations representing reactions and show the reaction structurally. Define hydrolysis.



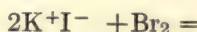
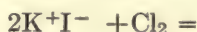
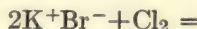
## IODINE

76. Prepare iodine by placing 3 g. pulverized KI and 2 g.  $\text{MnO}_2$  (mixture) in a porcelain crucible, A, Fig. 25, adding 5 cc. conc.  $\text{H}_2\text{SO}_4$ . Place the crucible in a 15 cm. porcelain dish B and cover it with a 7 cm. funnel C as shown in illustration. Heat very gently with a small flame until iodine vapors cease coming off. Dissolve the iodine deposited on the funnel in a little KI solution and preserve it for future experiments.

77. Place a little starch in a test-tube, add a few cubic centimeters of water and boil. Add a little of this solution to some water in another test-tube and then introduce *one* drop of the solution resulting from experiment 77. Note results. This is a test for iodine. Note that heat destroys the color which returns on cooling the solution.

78. To water containing a few drops of KBr solution add a drop of chlorine water and then pour some of this into dilute starch solution. Compare the color with that produced by iodine. Into another test-tube containing a little dilute KI solution pour a drop of chlorine water and make the starch test. Into still another containing dilute KI solution pour a drop of bromine water and make the starch test.

Complete the following equations showing ionization:



How would you test for free chlorine? For free bromine? For free iodine? How would you liberate these from their compounds in aqueous solutions?

## FLUORINE

**Warning.** Hydrogen fluoride vapors are very corrosive. If the acid comes in contact with the skin it produces burns which heal with great difficulty.

79. Into a lead dish introduce 3 g.  $\text{CaF}_2$  (calcium fluoride or fluorspar) and 5 cc. conc.  $\text{H}_2\text{SO}_4$ . If the latter should come in contact with your hands wash it off immediately. Cover the dish with a glass plate coated with paraffin on which a design has been traced by scraping off a little. The paraffin may be affixed to the plate by placing a small lump on the surface and warming until it melts

Set the covered dish aside *without heating* for at least one hour. Then remove the plate, wash in running water, dry and heat it until the paraffin melts, wiping it off on a dry cloth. Examine the surface of the glass. Supposing the glass to consist of a mixture of  $\text{CaSiO}_3$  and  $\text{Na}_2\text{SiO}_3$  write equations for the reactions which take place.

## THE HALOGENS. (GENERAL) $\text{F}_2 - \text{Cl}_2 - \text{Br}_2 - \text{I}_2$

Prepare an outline giving their atomic weights, specific gravity, states, color, odor, acids, compounds by direct union with Na or K, order of displacement by each other and tests.



**20. EFFECT OF SUBSTANCES IN SOLUTION ON THE FREEZING AND BOILING POINT**

Prepare a freezing mixture of ice, water and salt, using 23 parts by weight of salt for every 100 parts by weight of water and ice. Place this in a 500 cc. beaker.

**80.** Into a test-tube introduce 5 to 10 cc. of a solution of cane sugar ( $C_{12}H_{22}O_{11}$ ) containing 34.2 g. per 100 cc. water\*. Fit the test-tube with a two-hole stopper through which a thermometer† and stirrer have been introduced and keep the bulb covered with the solution. Agitate the wire in the freezing mixture observing the temperature at which ice crystals first form. Repeat with pure distilled water.

**81.** Into a test-tube pour 5 to 10 cc. of a solution containing 5.8 g. NaCl per 100 cc. solution. Proceed as in 80 and note results, repeating the experiment with a solution of double this strength.

**82.** Determine the boiling points of the above solutions, fitting flasks with two-hole stoppers, introducing the thermometer through one hole and a long glass tube through the other so as to condense escaping steam, and using 100 cc. of solution. Be sure that the thermometer bulb is in the solution.

How do unionized and ionized substances affect the freezing point? The boiling point? Of what use are these values to the chemist?

Define solvent; solute; molecule; ion; anion; cation. Describe molecular dissociation of two types. Mention various states in which ions are removed from solution by electrolysis. Define primary product of electrolysis; secondary product. Give examples.

\* This is the same strength as 342 g. (a mole, molar weight or gram-molecule) per liter. In experiment 81 we have the same concentration, i.e., a molar solution of salt containing 58.46 g. per liter.

† Purchase a 200° thermometer at the supply room and return it at the close of the laboratory period.



FIG. 26.



## 21. HYDROGEN PEROXIDE

**Warning.** Sodium peroxide produces painful burns, if brought in contact with the skin. *Do not handle it.* The action of moisture in the air is apt to create a sufficiently high temperature with  $\text{Na}_2\text{O}_2$  to ignite organic matter, so do not place the substance on paper, but keep it in a small *dry* porcelain dish until ready to use it. *Do not throw  $\text{Na}_2\text{O}_2$  into crocks containing paper.* Exposed to the atmosphere it deliquesces, so the compound should be used promptly.

**83. Preparation.** Into a 250 cc. Erlenmeyer flask pour 100 cc. distilled water. Then add 1 to 2 grams of  $\text{Na}_2\text{O}_2$  (sodium peroxide) cooling the contents by holding the flask under running water. With the flask still under running water, add *dilute*  $\text{H}_2\text{SO}_4$ , a drop at a time, until the solution turns blue litmus paper red. Write equations representing reactions.

**Note.**  $\text{Na}_2\text{O}_2$  is a powerful oxidizing agent. Added to an aqueous solution of  $\text{Cr}_2(\text{SO}_4)_3$  it will oxidize chromium to  $\text{Na}_2\text{CrO}_4$  raising the valence of Cr from 3 to 6. Write graphic formulas for both compounds to show the valence of Cr.

**84.** To a little cold  $\text{H}_2\text{O}_2$  solution in a test-tube add a drop of  $\text{H}_2\text{SO}_4$  and one of  $\text{KMnO}_4$  solution. Introduce a glowing splint of wood into the tube immediately above the solution and note results. What should happen if an oxidizable substance were present in the solution?

**85.** Into a second test-tube containing a little of the solution add a drop of  $\text{H}_2\text{SO}_4$  and one of  $\text{K}_2\text{Cr}_2\text{O}_7$  (potassium dichromate) solution. Note results. This is a test for  $\text{H}_2\text{O}_2$ .

**86.** Note the principal uses of  $\text{H}_2\text{O}_2$ . State the law of multiple proportion and illustrate using  $\text{H}_2\text{O}_2$  as an example. Why do manufacturers not sell pure concentrated  $\text{H}_2\text{O}_2$ ? Mention impurities which cause it to dissociate. How may the solution be preserved? Define oxidation; reduction; oxidizing agent; reducing agent.

**87.** Calculate the volume occupied by oxygen liberated from 100 g. of 3 per cent  $\text{H}_2\text{O}_2$  if the gas is measured at  $20^\circ \text{C}$ . under 740 mm. pressure.

**88.** How many grams of  $\text{Na}_2\text{O}_2$  are necessary for the preparation of a gram-molecular volume of oxygen.





## 22. IONIZATION, ETC.

Review experiments 58 and 59.

**Warning.** Pour acid into water when diluting same.

**89.** Using the apparatus described in experiment 28 and following directions given there electrolyze (1) a dilute solution of HCl (1 part conc. HCl in 20 parts  $H_2O$ ) and (2) a dilute solution of  $H_2SO_4$  (same proportions). Write equations (ionic, etc.) for *all* reactions which take place and account for results obtained. What would happen if you used concentrated HCl? Concentrated HCl saturated with  $Cl_2$ ?

**90.** Repeat experiment 89 with a dilute solution of NaOH (dilute one volume of molar NaOH solution with 10 volumes of water). Rinse your hands thoroughly immediately after inverting the tubes to mix the contents. Write equations for *all* reactions which take place.

**91.** Into five test-tubes placed in a beaker of cold water introduce respectively 5 cc. of 3N (3 normal)  $H_2SO_4$ , HCl,  $HC_2H_3O_2$  (acetic acid),  $H_3PO_4$  (phosphoric acid) and  $H_2C_2O_4$  (oxalic acid). Drop a 1 cm. square of pure sheet zinc into each and note the relative rate of evolution of  $H_2$ . Repeat the experiment, immersing the tubes in a beaker of hot water. List the acids in the order of their activity. Account for the differences in behavior on the basis of the theory of ionization. After having completed the experiments refer to the table on p. 241, Smith, General Chemistry for Colleges, and see whether your conclusions agree with data there given.

Define conductor; non-conductor; electrolyte; non-electrolyte; ion; cation; anion; cathode; anode; primary product of reaction; secondary product of reaction; equilibrium; ion product constant\*. *Give examples in each case.*

State Faraday's Law and illustrate with examples.

\* Review Experiment 70.





## 23. PROBLEMS

92. An electric current liberates 10.788 g. of silver from  $\text{AgNO}_3$  solution. Calculate weight of Al and  $\text{Cl}_2$  liberated by the same current. What volume will the chlorine occupy under standard conditions? At  $23^\circ$  under 756 mm. pressure?  $\text{Ag}=107.88$ ,  $\text{Al}=27.1$  and  $\text{Cl}=35.46$ .

93. Calculate the weight and volume of bromine liberated by  $\text{MnO}_2$  and  $\text{H}_2\text{SO}_4$  acting on 11.902 g.  $\text{KBr}$  if the gas is measured at  $70^\circ$  under 770 mm. pressure.  $\text{K}=39.10$ ,  $\text{Br}=79.92$ ,  $\text{Mn}=54.93$ ,  $\text{O}=16$ ,  $\text{H}=1.008$ ,  $\text{S}=32.06$ . Write equations for reactions.

94. Calculate the weight and volume of  $\text{HBr}$  formed by the action of  $\text{P}_4$  on 15.984 g.  $\text{Br}_2$  assuming that the water is already saturated with  $\text{HBr}$  and that all  $\text{HBr}$  formed passes over and is measured at  $22^\circ$  under 770 mm. pressure.  $\text{P}=31.04$ .

95. Prepare a neat sketch of the apparatus shown in your text book for the preparation of  $\text{HBr}$  from  $\text{P}_4$ ,  $\text{Br}_2$  and  $\text{H}_2\text{O}$ . Indicate the purpose of each part of the apparatus. Why cover the  $\text{P}_4$  with water instead of combining  $\text{P}_4$  and  $\text{Br}_2$  first and subsequently introducing the resulting compound into water? Prepare structural formulas of each compound used indicating how the substances react and what results. Write equations for all reactions.

96. Hydrogen iodide boils at  $34.1^\circ$  and iodine at  $184.35^\circ$ . What volume will 10 g. of the  $\text{HI}$  occupy at  $200^\circ$  under 730 mm. pressure assuming that there is neither association nor dissociation? What would the volume be if 3 per cent of the compound broke up into molecules of the constituents (these remaining undissociated and unassociated)?  $\text{I}=126.92$ .



## 24. SULPHUR

97. Heat a test-tube, one-third full of sulphur, gently until light yellow mobile sulphur is obtained. Increase the heat until the sulphur becomes dark brown and viscous. Hold the tube mouth down and note resistance to flow. Now continue heating until the sulphur again softens and pour it, in a thin stream, into a beaker of cold water. After the sulphur in the beaker has cooled sufficiently, press it between your fingers. Note all phenomena observed during the experiment. Dry the sulphur removed from the beaker and retain it for future experiments.

98. Place a few small pieces of roll sulphur in a test-tube. Introduce one or two cubic centimeters of  $\text{CS}_2$  (carbon bisulphide). Dissolve by shaking the tube.

**Warning.**  $\text{CS}_2$  is exceedingly inflammable and the vapor is poisonous. Pour the solution into a clock glass and let it evaporate on the window sill outside of one of the laboratory windows.

Try the solubility, in  $\text{CS}_2$ , of some of the plastic S.

Next place some crystals of sulphur on another clock glass, rest this on an asbestos square (in the hood) and heat until the dark brown viscous sulphur forms. Allow the solution to cool without disturbing it and note the appearance of the crystals. Compare their form with that of crystals obtained from the  $\text{CS}_2$  solution which was evaporated.

Which of the two is alpha sulphur? Which beta sulphur? Which of the above is gamma sulphur? Name the crystalline forms of alpha and beta sulphur.

Define allotropism and give examples in one other element already studied.

99. Pulverize some roll sulphur or weigh a quantity of flowers of sulphur sufficient to form  $\text{FeS}$  (ferrous sulphide) with 5 g. pulverized Fe. Mix the two thoroughly and heat in a dry *hard-glass* test-tube until the reaction is complete. Note a phenomenon which seems to indicate that heat is generated by the chemical reaction. Allow the tube and contents to cool and preserve it for future experiments. Write equation for reaction and show calculations which you made to determine the amount of sulphur required. Atomic weights:  $\text{Fe} = 55.84$ ,  $\text{S} = 32.06$ .

100. Note molecular formulas of sulphur vapor at  $250^\circ \text{C}$ .,  $800^\circ \text{C}$ ., and  $2000^\circ \text{C}$ . How are they calculated? What is the specific heat of sulphur? How may the atomic weight be estimated from this value by the law of DuLong and Petit? Show calculations.





## 25. HYDROGEN SULPHIDE AND SULPHUR DIOXIDE

**Warning.** *Hydrogen sulphide is poisonous, so experiments should be conducted under the hood.*

**101.** Place the  $\text{FeS}$  (ferrous sulphide) prepared in experiment 99 in a 250 cc. Erlenmeyer flask, and after the test-tubes containing solutions indicated in the following paragraphs are ready, introduce into the flask a solution of 5 cc. concentrated  $\text{H}_2\text{SO}_4$  diluted with 20 cc.  $\text{H}_2\text{O}$ . Immediately fit the flask with a singly perforated rubber stopper bearing a right-angle tube extending just below the stopper. To this attach a rubber tube and a 15 cm. delivery tube. *Be sure to have the apparatus complete and the test-tubes filled as directed before introducing the acid into the Erlenmeyer flask.* Connect the exit tube from  $\text{H}_2\text{S}$  generator with tube passing through the one-hole stopper of test-tube as shown in Fig. 27, shaking the test-tube from time to time. If the supply of  $\text{H}_2\text{S}$  is insufficient purchase more  $\text{FeS}$  at the supply room.

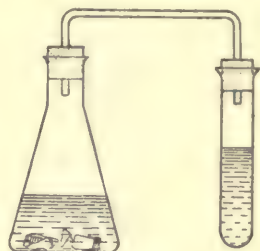


FIG. 27.

Into a series of test-tubes, about one-third filled with water introduce two or three drops of each of the following:  $\text{AsCl}_3$  (arsenious chloride),  $\text{CdCl}_2$  (cadmium chloride),  $\text{SbCl}_3$  (antimonious chloride),  $\text{CuSO}_4$  (copper sulphate). Add two drops of concentrated  $\text{HCl}$  to each.

Into another series containing the same amount of water pour a few drops each of  $\text{AgNO}_3$  (silver nitrate) and  $\text{Pb}(\text{NO}_3)_2$  (lead nitrate).

Into a third series containing water pour a few drops of  $\text{ZnSO}_4$  and  $\text{MnSO}_4$  (manganese sulphate). To each tube add a little  $\text{NH}_4\text{Cl}$  solution and one drop of  $\text{NH}_4\text{OH}$  (ammonium hydroxide).

Write equations showing reactions which take place excluding the  $\text{NH}_4\text{OH}$  and  $\text{NH}_4\text{Cl}$ . Of what use are these and similar reactions in analytical chemistry?

Try the action of a little dilute  $\text{H}_2\text{SO}_4$  on the sulphides of zinc and manganese. What happens? How would you account for the changes? Write equations representing reactions.

State the law which is illustrated by the method used for treating solutions with  $\text{H}_2\text{S}$ .

**102.** Into a test-tube to be subsequently fitted with a one-hole stopper and outlet tube introduce a few  $\text{NaHSO}_3$  (sodium sulphite) crystals. Add a little dilute  $\text{H}_2\text{SO}_4$  and pass the resulting gas into water containing a little litmus solution. Repeat with water containing a drop of  $\text{KMnO}_4$  solution. Note results and equations for all reactions except with litmus.

**103.** Into another test-tube, outlet same as that in 102, introduce a few small pieces of copper and a little concentrated  $\text{H}_2\text{SO}_4$ . Heat *gently* until action starts and again pass the gas through litmus and  $\text{KMnO}_4$  solution. Note results and equation for the  $\text{SO}_2$  preparation reaction.

**104.** Write a number of equations representing the reducing action of  $\text{H}_2\text{S}$  and  $\text{SO}_2$  on  $\text{K}_2\text{Cr}_2\text{O}_7$ , or  $\text{KMnO}_4$  or  $\text{Fe}_2(\text{SO}_4)_3$ . By equations compare the action on  $\text{KMnO}_4$  first of  $\text{H}_2\text{S}$  in presence of  $\text{H}_2\text{SO}_4$  and second  $\text{HCl}$  alone.

**105.** Calculate the amount of  $\text{FeS}_2$  necessary for the preparation of a gram-molecular volume of  $\text{SO}_2$ . Show equation and calculations.





## 26. SULPHUR TRIOXIDE AND SULPHURIC ACID

Students may work in pairs, each presenting a separate report.

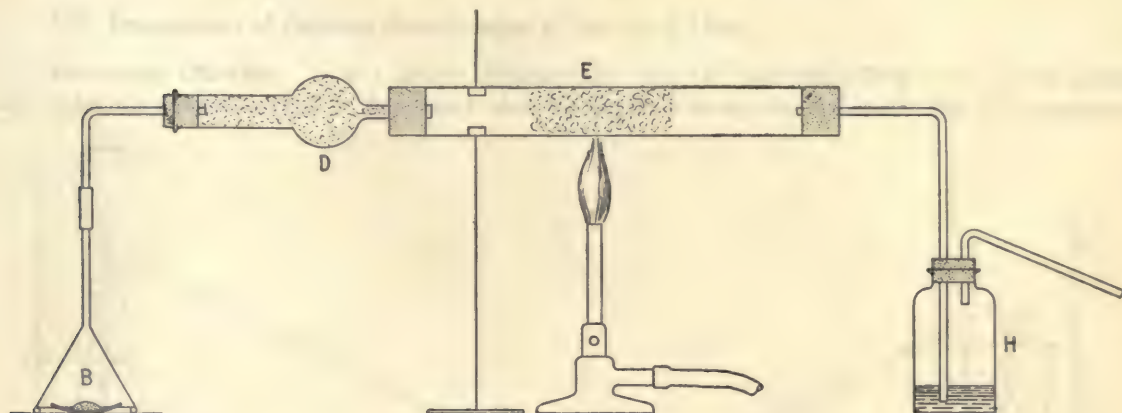


FIG. 28.

**106.** On a small watch glass *B*, place several lumps of sulphur each about the size of a pea. The watch glass rests on an asbestos square. Over this place a 75 mm. funnel. With the funnel outlet, connect drying tube *D* containing  $\text{CaCl}_2$ . (If you still have the drying tube used in former experiments and the  $\text{CaCl}_2$  is dry, this will do.) Then connect a combustion tube *E*. *E* contains some dry  $\text{Fe}_2\text{O}_3$  (ferric oxide) mixed with asbestos wool. Next connect with inlet tube of bottle *H*, which contains about 25 cc. water. Start suction at the rate of two or three bubbles per second through solution *H*, place a small flame under the  $\text{Fe}_2\text{O}_3$ , gradually increasing the heat, and then ignite the sulphur in *B*, letting the funnel rest on thin glass rods or match sticks at three points to admit air. Allow the experiment to run until the sulphur is completely consumed.

Write equations representing reactions and state in which parts of the apparatus the reactions take place.

Define catalytic or contact agent and mention an experiment for the production of another substance where a catalytic agent was employed, giving the name of the catalyzer and describing its effect on the speed of the reaction, and the temperature at which the reaction takes place. Mention another catalyzer which might be employed in the manufacture of sulphuric acid.

**107.** To a little of the solution from bottle *H* in a test-tube add several drops of dilute  $\text{HCl}$  and then a drop or two of  $\text{BaCl}_2$  (barium chloride). Note result and write ionic equation representing the reaction. Now add some  $\text{BaCl}_2$  to a little  $\text{H}_2\text{SO}_3$  (sulphurous acid) from the reagent shelf and subsequently add a little dilute  $\text{HCl}$ . Note results and write equations for the reactions.  $\text{BaCl}_2$  is a test for the  $\text{SO}_4$  ion, if added in the presence of dilute  $\text{HCl}$  or  $\text{HNO}_3$ .

**108.** Place the remainder of the solution from bottle *H* in an evaporating dish and heat in the hood until dense white fumes begin to be evolved and the liquid assumes a syrupy appearance. Allow the dish to cool slowly in the air. Now introduce a match stick or a little granulated sugar.

Sulphuric acid is a drying agent for gases which do not react with it. These are allowed to bubble through the acid. Mention several gases which might be dried in this way.



## 27. HYPOCHLORITES AND CHLORATES

## 109. Preparation of Calcium Hypochlorite (Chloride of Lime).

**Potassium Chlorate.** Into a 250 cc. Erlenmeyer flask (*E*) introduce 20 g. CaO (quick lime) and slake it by introducing 7 cc. hot water, shaking the flask to agitate and insure the disintegration

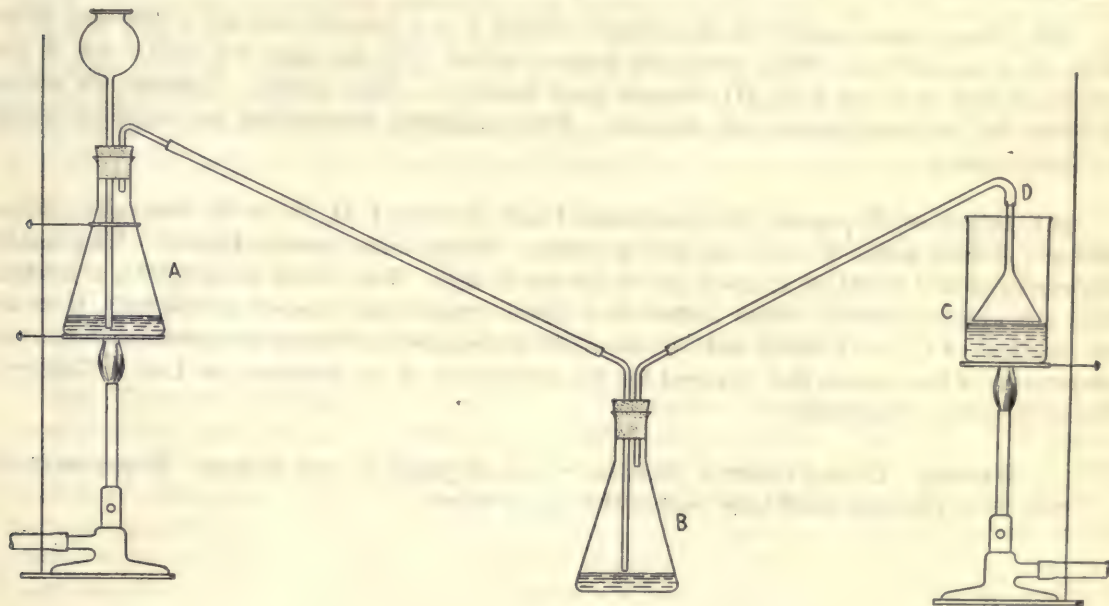


FIG. 29.

of the contents. Fit the flask with a two-hole stopper containing a long tube reaching nearly to the bottom of the flask and a short outlet tube. Into a beaker *C*, introduce 60 cc. of KOH (potassium hydroxide) solution obtainable at the supply room.

**Warning.** KOH attacks the skin and dissolves wool, so be careful not to bring it into contact with your hands or clothing.

Heat the solution using a very small flame, and suspend a funnel, *D*, so that it reaches just below the surface of the liquid. Into a 500 cc. Erlenmeyer flask *A*, resting on an asbestos square introduce 60 g.  $\text{MnO}_2$  and 100 cc. of 1.1 HCl (half acid and half water). More of the acid may be used from time to time as needed. Connect the outlet tube from *A* to the inlet tube for *B* by a long rubber tube and the outlet from *B* with the funnel *D* by another long rubber tube. *A* and *C* are to be heated in the hood but *B* should be cold and kept outside the hood. After  $\text{Cl}_2$  has begun to generate shake *B* for about twenty minutes so as to agitate the contents. Then disconnect the flask, connecting the two rubber tubes by a



small glass tube. Remove the stopper from *B* and leave the flask in the hood until the free  $\text{Cl}_2$  has escaped. Continue to pass  $\text{Cl}_2$  through the solution in *C* until it no longer turns litmus paper blue but gives a red color which immediately bleaches due to an excess of  $\text{Cl}_2$ . Then remove the funnel which can be lowered into the vent pipe at the side of the hood until the generation of  $\text{Cl}_2$  ceases. Heat the solution in *C* until a rod lowered into it shows crystals on being removed. Cool the solution by placing the beaker in water. When cold filter off the crystals, labeling same Crop I.

Heat the remaining solutions again to crystallization, filter and mark crystals Crop II. Evaporate the remaining solution to dryness and mark the residue Crop III. Write equations representing reactions which take place in vessels *B* and *C*. Note that hypochlorites form in the cold, and chlorates in hot solutions of hydroxides.

110. Place a small quantity of the contents of flask *B* in a test-tube and add a little *very dilute*  $\text{HCl}$ . Is a gas evolved? What would you judge it to be? Try the same test with a few of the crystals of each of Crops I, II, III obtained from beaker *C*. Note results. Compare the action of dilute  $\text{HCl}$  on hypochlorites and chlorates. Write equations representing any reactions which you have noticed.

111. Heat a small quantity of the crystals of each of Crops I, II, III in dry test-tubes, introducing a glowing splint of wood and noting results. Which crops contain  $\text{KClO}_3$ ? Why would you expect to find  $\text{KClO}_3$  in Crops I and II and not in III? What forms when  $\text{KClO}_3$  is heated, fuses and again solidifies? When heated to a higher temperature, melted and boiled? How do the reactions of  $\text{Cl}_2$  with alkali and alkaline-earth hydroxides at various temperatures, from the temperature of the room to that required for the preparation of  $\text{O}_2$ , illustrate the Law of Consecutive or Successive Reactions?

**Warning.** Do not preserve chlorate crystals in paper in your lockers. If you want to save them purchase small tube vials at the supply room.

## 28. ELECTROLYTIC PREPARATION OF HYPOCHLORITES AND CHLORATES

**Warning.** Do not turn current on until you are ready to begin the electrolysis. *Never handle electrical connections with wet hands.*

**112. Hypochlorites.** Dissolve 25 grams of common salt in 100 cc. distilled water in a 200 cc. beaker. Introduce two graphite electrodes (obtainable at supply room and to be returned at close of period) supported by burette clamps attached to an iron stand. Insulate the electrodes by slipping small pieces of rubber tubing over the parts held by the burette clamps. Place the beaker in the hood and connect the graphite poles with wires leading to the 110-volt direct-current circuit, using a 60-watt carbon lamp in series as a resistance. Turn the current on and allow the electrolysis to continue for one hour. *Keep the solution cold* by placing the beaker in a dish of cold water.

Remove the electrodes, pass a stream of air through the solution by introducing a glass tube into it and making a rubber connection with the compressed air line. When the solution no longer smells of chlorine turn off the air. Then place a little of the solution in a test-tube and add a few drops of very dilute HCl. Also try the action of dilute HCl and NaCl. Note results. Write equations representing reactions which take place in the electrolysis and tests.

**113. Chlorates.** Prepare a solution of 25 g. KCl (potassium chloride, obtainable at supply room) in 100 cc. water, heat and electrolyze for one hour same as above. Turn current off, remove electrodes and evaporate to crystallization. If the solution looks gray because of carbon particles which have fallen from the electrodes, filter before crystallizing, as carbon mixed with  $\text{KClO}_3$  is apt to cause a serious explosion. Filter the crystals, transfer them to a watch crystal, dry them in a steam oven and place a few in a dry test-tube, repeating test for liberated oxygen, as described in earlier experiments. Try the same test on some of the original KCl. Note results and write equations representing reactions which take place in the electrolysis and tests.





## 29. PROBLEMS

Write equations for all reactions involved in the following problems; also all ratios by formulas and numbers.

**114.** Calculate the theoretical quantity of  $\text{CaClOCl}$ ,  $\text{KCl}$  and  $\text{KClO}_3$  formed in experiment 109, assuming that you started with exact quantities of the raw materials and that the  $\text{KOH}$  solution contained 30 per cent by weight.

Calculate the theoretical weight of  $\text{MnO}_2$  necessary for the production of the chlorine required to form the compounds assuming no loss of chlorine.

Calculate the theoretical weight of an aqueous solution of  $\text{HCl}$  containing 20 per cent by weight of  $\text{HCl}$ , necessary for the preparation of the chlorine.

The  $\text{HCl}$  solution has a specific gravity of 1.1006. How many cc. will be required?

Estimate the theoretical volume of  $\text{Cl}_2$  measured at  $20^\circ \text{C}$ . under 740 mm. pressure, that will result from the decomposition of the  $\text{CaClOCl}$  by  $\text{HCl}$ .

Also calculate the per cent of *available* chlorine in the bleaching powder ( $\text{CaClOCl}$ ).

$\text{Ca} = 40.07$ ,  $\text{Cl} = 35.46$ ,  $\text{H} = 1.008$ ,  $\text{O} = 16$ ,  $\text{K} = 39.10$ ,  $\text{Mn} = 54.93$ .



## 30. NITROGEN AND AMMONIA

**115. Preparation of Nitrogen.** As there is usually only one experiment with pure  $N_2$  it seems unnecessary for the student to prepare the element. Still, it is desirable that he have a good method for preparing it, so the following, which has already been demonstrated in the lectures, is given. Flask A, 1000 cc. capacity (Fig. 28), contains a saturated solution of  $NH_4Cl$  (ammonium chloride,

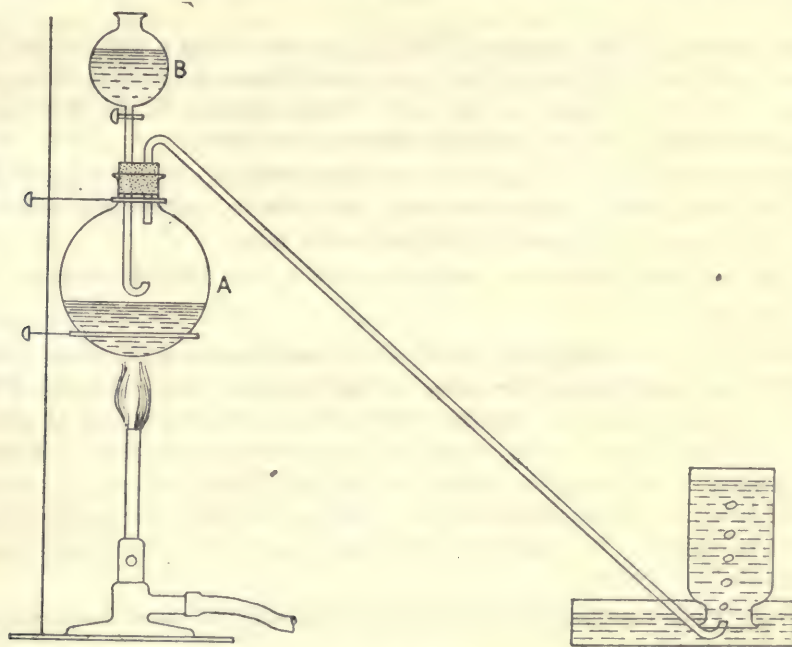
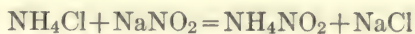


FIG. 30.

37 g. in 100 cc.  $H_2O$  at  $20^\circ$ ). This is heated to boiling and a saturated solution of  $NaNO_2$  (sodium nitrite, 82 g. in 100 cc.  $H_2O$  at  $20^\circ$ ) is dropped in *very slowly* from a separatory funnel B. As each drop of  $NaNO_2$  strikes the hot  $NH_4Cl$  solution the following reactions take place:



and a steady stream of  $N_2$  is obtained without the danger of an explosion which frequently results with the older method of procedure where  $NH_4NO_2$  solution was heated.

**116. Preparation of Ammonia.** Fit a 500 cc. Erlenmeyer flask with a one-hole stopper and outlet tube extending just through the stopper on the under side. The flask should rest in water in a 150 mm. dish. Fit a bottle one-fourth full of water with a two-hole stopper, an inlet tube extending half an inch *above* the level of the water and an outlet tube just through the under surface of the



stopper. The outlet tube from this bottle should be bent over and should extend to within half an inch of the water level in second bottle (open). Into the flask introduce a mixture of 30 g.  $\text{NH}_4\text{Cl}$  and 25 g.  $\text{Ca}(\text{OH})_2$  both pulverized. Shake so as to mix thoroughly. Introduce the stopper. Heat the dish gradually, collecting  $\text{NH}_3$  in several *perfectly dry* bottles by displacement of air, same as in  $\text{H}_2$  experiments. You can tell when the bottles are full by holding a moist strip of red litmus paper below the mouth until it turns blue. Place these bottles mouth down over *dry* glass plates. Then connect the outlet from the flask with the two bottles containing water. Allow the generator to run until  $\text{NH}_3$  ceases to come over. Give equations for reactions which take place.

117. Fill your sink three-fourths full with water. Place the second bottle of  $\text{NH}_3$  mouth downward about one-half inch below the surface and remove the glass plate. Note result and explain the phenomenon.

118. Test the solution of  $\text{NH}_3$  in water,  $\text{NH}_4\text{OH}$ , by introducing a strip of red litmus paper. Is  $\text{NH}_4\text{OH}$  an acid or a base? Try the action on moist red litmus paper held above the solution? Define dissociation. How does it apply in this case? Write equation for the dissociation and also for the ionization of  $\text{NH}_4\text{OH}$ . Why is ammonia called a weak base?

To a little  $\text{NH}_4\text{OH}$  solution in a 75-mm. dish add dilute  $\text{HCl}$  a drop at a time until blue litmus paper just turns red. Evaporate slowly to dryness. When dry place the dish over a small flame and note results. This action is characteristic of ammonium salts.

Hold a glass rod, previously dipped in concentrated  $\text{HCl}$ , over  $\text{NH}_4\text{OH}$  solution. Note results and equation for reaction.

119. To a little  $\text{NH}_4\text{Cl}$  or  $(\text{NH}_4)_2\text{SO}_4$  solution in a small beaker add a little  $\text{NaOH}$  solution. Cover the beaker with a watch glass to the under or convex surface of which a bit of filter paper is affixed by touching it with a drop of a mixture of five drops of  $\text{H}_2\text{O}$ +1 drop of phenolphthalein solution. Phenolphthalein paper is more convenient, but not always available. Warm the beaker gently and note results. Care must be taken to prevent  $\text{NaOH}$  from coming into contact with the upper edge of the beaker, as steam might condense, carrying this down the watch crystal into contact with the phenolphthalein. Through such carelessness ammonia is sometimes reported though not present in the substance tested.

The test here described together with the fumes formed with  $\text{HCl}$  and the pungent odor of the gas serve to identify ammonia.

120. Place about half a gram of cotton seed meal in a dry 500 cc. Erlenmeyer flask and introduce 15 cc. concentrated  $\text{H}_2\text{SO}_4$ . Let a porcelain crucible rest in the mouth of the flask which is now placed on an asbestos square *in the hood*. Heat for fifteen minutes over a *very small flame*, and then increase the heat so the acid begins to boil. Keep the *hood windows down* during the entire operation. Continue to boil until the solution, at first black, is straw yellow or colorless. The sulphuric acid oxidizes the nitrogen in protein to ammonia. The excess of  $\text{H}_2\text{SO}_4$  insures formation of  $(\text{NH}_4)_2\text{SO}_4$ . This method of converting nitrogen to ammonia is used in food analysis. Cool, dilute with 50 cc. water and introduce 25 or 30 cc.  $\text{NaOH}$  (50 per cent solution). Handle with greatest of care as this solution is extremely caustic. Hold a piece of moist red litmus over the mouth of the flask. Also test with a rod dipped in concentrated  $\text{HCl}$ . Ammonia is liberated by treating the flask contents with  $\text{NaOH}$  and distilling the ammonia over into a definite volume of tenth normal acid solution. The amount of acid neutralized indicates the amount of ammonia formed. From this in turn one can calculate nitrogen and multiplying the nitrogen value by the factor 6.25 the amount of crude protein is calculated. The protein value of foods is important and so the principle involved is given above though not usually included in first-year laboratory manuals.

## 31. NITROGEN (OXIDES AND ACIDS)

**Warning.** The oxides of nitrogen are poisonous. Work carefully so as to avoid their escaping into the atmosphere of the laboratory.

**121. Nitrous Oxide.** Into a 250 cc. Erlenmeyer flask, fitted with a one-hole stopper and delivery tube, introduce 10 grams  $\text{NH}_4\text{NO}_3$  (ammonium nitrate) and heat gently, collecting the gas in several bottles by displacement of water. Write equation for reaction. Into one of the bottles introduce a glowing splint of wood. Into another a little burning sulphur. Note results. Which element previously studied resembles this compound in its reactions?

**122. Nitric Oxide.** Into a 250 cc. Erlenmeyer flask introduce several pieces of Cu and about 5 cc. dilute  $\text{HNO}_3$  (sp.gr. 1.2). Collect the gas over water, warming the flask a little if necessary. Introduce a match into the gas. Does it support combustion? Compare with  $\text{N}_2\text{O}$ . Note the change in color when the gas is exposed to air. What forms? Write equations for the various reactions.

**123. Nitric Acid.** Into a glass retort introduce 10 grams  $\text{NaNO}_3$  (sodium nitrate) and 15 cc. conc.  $\text{H}_2\text{SO}_4$ , the latter through a funnel. Stopper the retort and introduce the tube into a small Erlenmeyer flask which in turn rests in cold water. Heat gently until most of the  $\text{HNO}_3$  (nitric acid) is distilled over. *Avoid too high a temperature* as this will cause the  $\text{H}_2\text{SO}_4$  to dissociate and spoil the experiment. Perform the experiment in the hood.

**124.** Try the effect of a little of the distillate diluted with an equal volume of water on a bit of Cu, Zn and Pb. Write equations for the reactions.

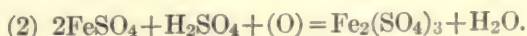
Place a little of the strong acid in a *dry* test-tube and introduce a small tuft of wool or yarn at the mouth of the tube. Heat. Note results and account for same.

Introduce a splinter of wood into a little concentrated acid and note change in appearance.

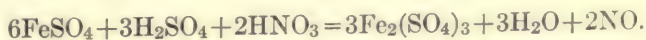
Dilute a little of the acid and try the action on blue litmus paper.

**125. Test for Nitrates.** Into a test-tube introduce a few drops of  $\text{KNO}_3$  or  $\text{NaNO}_3$  solution from the reagent shelf. Dilute with a *very little* water and then add an equal volume of conc.  $\text{H}_2\text{SO}_4$ . Cool the tube in running water and allow about 2 cc. of strong  $\text{FeSO}_4$  (ferrous sulphate) solution to run slowly down the side of the tube so as to prevent the mixing of the two liquids.

When the  $(\text{NO}_3)$  ion is present in substances tested a brown ring forms at the juncture of the  $\text{FeSO}_4$  and  $\text{H}_2\text{SO}_4$  solutions. Equations offered to explain the reactions are:



Combining equations 1 and 2 ( $\times 3$ ):



The nitric oxide is supposed to form an unstable compound of the formula  $\text{FeSO}_4 \cdot \text{NO}$  with the excess ferrous sulphate.





## 32. PREPARATION OF GUN COTTON

**Warning.** If strong acids come in contact with the skin wash immediately in running water and then apply a solution or paste of sodium bicarbonate. If the burn is severe apply a mixture of lime water and linseed oil.

**126.** Into a 100 cc. beaker introduce 20 cc. conc.  $\text{HNO}_3$  and 20 cc. conc.  $\text{H}_2\text{SO}_4$ . Cool the mixture by placing the beaker in a porcelain dish containing water, and stirring. Shred about 2 grams cotton into fine tufts and drop these into the mixture of acids, pressing each down in turn with a glass rod. When all the cotton has been introduced cover the beaker and set it in the hood for fifteen minutes.

Lift the cotton out on a glass rod and drop it into a large beaker of water. Remove the bulk of the acid retained by the cotton, by rinsing repeatedly and then do the final washing in running water until the cotton no longer tastes sour or reacts with blue litmus paper pressed against it.

Dry the cotton by squeezing out as much of the water as possible and then press it between filter papers. Shred it to as fluffy a consistency as possible and dry at room temperature. When perfectly dry ignite the cotton. Compare the rate of combustion with that of ordinary cotton by igniting a little of the latter. *Do not store gun cotton in your desk* or throw it into waste crocks. Ignite the entire product of the experiment.

The cotton or cellulose contains OH groups which are replaced by the  $\text{NO}_3$  radical of the nitric acid.  $\text{H}_2\text{SO}_4$  serves as dehydrating agent, taking up the water formed by the H from the nitric acid and OH from the cellulose.

**127.** Twenty-five grams of  $\text{H}_2\text{SO}_4$  solution required 10.2 cc. of 0.12 N NaOH for neutralization. Calculate the percent by weight of  $\text{H}_2\text{SO}_4$  in the aqueous solution.  $\text{H}=1.008$ ,  $\text{S}=32.06$ ,  $\text{O}=16$ ,  $\text{Na}=23$ .



## 33. PHOSPHORUS AND COMPOUNDS

**128.** Place some red phosphorus, about the size of a pea, in a porcelain combustion boat and this, in turn, in a hard-glass combustion tube. Fit the tube with one-hole stoppers. The inlet is fitted with a glass tube reaching just to the boat and is connected with the compressed-air line. The outlet is fitted with a delivery tube which extends below the surface of the water in a test-tube. Start the air so that it passes through the solution at the rate of about two bubbles per second. Then heat the tube under the boat until the phosphorus takes fire when the burner may be removed. When all the phosphorus has been converted to oxide allow the tube to cool and rinse it with a little water sprayed in from a wash bottle. Add the washings to the solution in the test-tube.

**129.** (a) To a portion of the solution obtained in 128 add a drop of *dilute*  $\text{KMnO}_4$  solution and warm. Note change. What does this indicate?

(b) To another portion add  $\text{NaHCO}_3$  (sodium bicarbonate) solution, a drop at a time, until neutral and then a drop of  $\text{AgNO}_3$  (silver nitrate solution). Note results and write equations for reactions.

(c) To a third portion add a drop or two of albumin solution, acidified with dilute  $\text{HC}_2\text{H}_3\text{O}_2$  (acetic acid). Note results.

**130.** To a little  $\text{Na}_2\text{HPO}_4$  (di-sodium hydrogen orthophosphate, sold commercially as sodium phosphate), diluted with water, add the second reagent indicated in 129b. If a precipitate forms the first reagent is not necessary. Why? Compare results with 129b. Give equations for reaction.

To a solution of  $\text{NaPO}_3$  (sodium metaphosphate) add the reagent indicated in 129c. Compare results.

To some  $\text{Na}_4\text{P}_2\text{O}_7$  (sodium pyrophosphate) solution add a drop of  $\text{AgNO}_3$  and compare the color with that obtained in  $\text{Na}_2\text{HPO}_4$  solution. Give equation for reaction.

These three reactions serve to identify ortho, meta and pyrophosphoric acids.

**131.** To a little  $\text{MgSO}_4$  (magnesium sulphate) solution add a little  $\text{NH}_4\text{OH}$  and considerable  $\text{NH}_4\text{Cl}$ . This is known as "Magnesia Mixture." Now add a little of the solution to an orthophosphate solution and note results. Write equation for reaction, ignoring the  $\text{NH}_4\text{Cl}$ . This method is used for the quantitative estimation of magnesium and phosphates. Add  $\text{HCl}$  to the precipitates. What happens? Write equation for reaction. Magnesia mixture is a test for the orthophosphate ion.

**132.** Heat a piece of 6 mm. glass tubing until the end is almost closed, then introduce your platinum wire to a depth of about 5 mm. and heat again until the wire is fused into the glass. Form a loop of about 3 mm. diameter on the end of the wire by wrapping it around the pointed end of your pencil or a thin glass rod. Heat the wire to redness and dip it into dry sodium phosphate. Heat



again until a clear glass bead is obtained and then touch this with a *minute* speck of  $\text{CoO}$  (cobalt oxide) about the size of a pin point. Heat once more until a clear colored bead is obtained. Try the effect of both the reducing and oxidizing zone of the blowpipe flame. When cool the bead may be removed by unwrapping the wire. Repeat the experiment with fresh portions of sodium phosphate adding *minute* quantities of  $\text{MnO}_2$ ,  $\text{Cr}_2\text{O}_3$  (chromium oxide) and  $\text{CuO}$ . Note results. These bead colors serve as preliminary tests to identify the metals studied in qualitative analysis.

**133.** Calculate the quantity of phosphorous acid obtainable from 10 g. red phosphorus. How much phosphoric acid would result.  $\text{H} = 1.008$ ,  $\text{P} = 31.04$ ,  $\text{O} = 16$ .

**134.** Calculate the percentage composition of di-sodium hydrogen orthophosphate.  $\text{Na} = 23$ ,  $\text{H} = 1.008$ ,  $\text{P} = 31.04$ ,  $\text{O} = 16$ .

**135.** Figure the volume of pure air at  $23^\circ$  under a pressure of 750 mm. which will be required for the preparation of each of the acids in 133.

**136.** Show the structural formulas for phosphorus trioxide, phosphorous acid, ortho, meta, pyrophosphoric acids and phosphorus pentoxide, and show graphically how the last three are derived from the ortho acid.

## 34. CARBON

**137. Destructive Distillation of Coal.** Into a hard glass test-tube introduce 10 g. of soft coal about the size of peas. Fit the tube with a one-hole rubber stopper and an outlet tube which passes to within an inch of the bottom of a 300 cc. Erlenmeyer flask through a two-hole rubber stopper. The Erlenmeyer flask should rest in a beaker of cold water. The outlet tube from the flask should run to the bottom of a bottle containing half an inch of water. The outlet from this leads to the pneumatic trough in which several bottles filled with water are inverted for the collection of the gas formed.

Apply heat gradually to the test-tube containing the coal and continue heating until no more gas is evolved. Be careful not to heat the upper part of the tube as this would decompose the rubber stopper. Ignite the gas in each bottle as some CO is present and it would be dangerous to let this escape into the room.

Exact weight of coal taken..... g.  
Volume of gas obtained..... cc.

**138.** To about 25 cc. of the wash water from the bottle, add NaOH and test for ammonia. Give equation for reaction.

**139.** Evaporate the contents of the Erlenmeyer flask in a small porcelain dish over a beaker containing water and note consistency and odor of the residue.

**140.** Place 1 gram of pulverized coal in a weighed porcelain crucible (covered) on a pipe-stem triangle and heat very slowly *in the hood* to drive off volatile matter. Cool the crucible and contents, and weigh. Then remove the lid and incline the crucible, resting the lid against it, and continue heating until a light ash results. The crucible contents may be stirred with a clean platinum wire from time to time, toward the end of the heating, so as to hasten combustion of small carbon particles. When you think that all the carbon has been consumed, cool the crucible and weigh it. Heat once more for ten minutes, cool and weigh again. If this weight agrees with the first calculate the per cent of ash in the coal. *Too high a temperature should be avoided* as the ash contains salts of alkali metals, some of which are volatile above dull red heat.

Note that for certain industrial purposes it is also important to determine the sulphur content of coals.

Weight of crucible+coal..... g.  
Weight of crucible..... g  
Weight of coal..... g.  
Weight of crucible+coal..... g.  
Weight of crucible+contents after driving off volatile matter.... g.  
Weight of volatile matter..... g.  
Per cent of volatile matter..... per cent  
Weight of crucible+ash..... g.  
Weight of crucible..... g.  
Weight of ash..... g.  
Per cent of ash..... per cent

**141.** One cc. of amorphous carbon will adsorb 171 cc. of  $\text{NH}_3$  under standard conditions. The specific gravity of the carbon is 1.75. It requires 1 sq. cm. of plain surface to adsorb 0.00000004 g. of  $\text{NH}_3$ . Calculate the adsorption surface of 1 g. of this carbon.  $\text{C} = 12.005$ ,  $\text{N} = 14.01$ ,  $\text{H} = 1.008$ .





## 35. CARBON COMPOUNDS

## METHANE

**142.** Prepare a mixture containing 8 g. soda lime and 5 g.  $\text{NaC}_2\text{H}_3\text{O}_2$  (sodium acetate). Place it in a *hard glass* test-tube or iron tube fitted with a one-hole stopper and a delivery tube which runs to the pneumatic trough. Collect several bottles of the gas generated by heating the test-tube. Why use soda lime in preference to  $\text{NaOH}$ ? Note results and write equation for reaction.

## ACETYLENE

**143.** Place a small gelatine capsule containing  $\text{CaC}_2$  (calcium carbide) under a bottle, filled with water, inverted in the pneumatic trough. Allow it to stand until the capsule dissolves and gas generates. Then ignite the gas formed. Note results and account for the combustion phenomena. Write equations for reactions of formation of calcium carbide and acetylene.

## FLAME

**144.** Introduce the head of a safety match into the inner cone of a Bunsen flame and let the stick rest on the top of the burner. This must be done quickly. Note results and account for same. Now raise the match into the second cone and note results. Sketch the various cones in a flame and explain the changes taking place in each.

**145.** Bring a piece of paper over a flame about half an inch above a Bunsen burner and as soon as the paper chars remove it. Note the form of the charred part and account for same.

**146.** Place a little  $\text{PbO}$  (lead oxide) in a hollow made in a piece of charcoal and heat in the *inner* part of a blowpipe flame. The blowpipe is operated by resting it on the supporting ledge of a blowpipe tip which fits over the Bunsen burner. Close the air vent in the burner and use a flame about 1 in. high. Now blow into the brass pipe and direct the flame slightly downward onto the  $\text{PbO}$ . Continue heating for about ten minutes and note results. Write equation for reaction.

Into another hollow introduce a small piece of metallic lead and heat with the *tip* of the blowpipe flame. Note results and write equation for reaction.

Prepare a small cavity in a stick of charcoal, mixing the carbon removed with a little  $\text{SnO}_2$  (tin oxide) and heat in the reducing zone of a blowpipe flame.

Repeat using  $\text{Bi}_2\text{O}_3$  (bismuth trioxide). Write equations for reactions. What is a substance which acts as charcoal does here, called?

Define reducing flame; oxidizing flame; locate these in the blowpipe flame and prepare a sketch to show both parts.

## CARBON DIOXIDE

**147.** Place two or three pieces of charcoal, pea size, in a combustion tube, heat to redness and pass compressed air through at the rate of about two bubbles per second. Connect the outlet

with a wash bottle containing  $\text{Ca(OH)}_2$  solution (calcium hydroxide, also known as lime water) and have the outlet from this run to the vent pipe in the hood. Why the last precaution? Give equations for reactions.

**148.** Into a *hard glass* or iron tube introduce  $\text{CaCO}_3$  to a depth of about half an inch. Fit the tube with a one-hole stopper and outlet tube running to the bottom of a test-tube containing  $\text{Ca(OH)}_2$  solution. Heat. Note results and write equations for reactions.

Repeat the experiment, using  $\text{NaHCO}_3$  (sodium bicarbonate or acid carbonate).

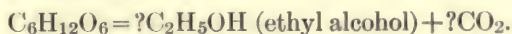
**149.** Into a test-tube introduce a small piece of marble and add a little dilute  $\text{HCl}$ . Pass the gas through  $\text{Ca(OH)}_2$  solution. Note results and equations for reactions. Try the action of the gas on moist blue litmus paper. Collect a bottle of  $\text{CO}_2$  and introduce a piece of burning magnesium ribbon. Note results and write equation for reaction.

**150.** Into a series of test-tubes introduce *dilute* solutions of  $\text{ZnSO}_4$ ,  $\text{FeCl}_3$  (ferric chloride),  $\text{Ni(NO}_3)_2$  (nickel nitrate),  $\text{CuSO}_4$ ,  $\text{Co(NO}_3)_2$  (cobalt nitrate),  $\text{BaCl}_2$  and  $\text{CaCl}_2$ . Try the action of  $\text{Na}_2\text{CO}_3$  and  $(\text{NH}_4)_2\text{CO}_3$  on each. Note that the alkali carbonates are soluble in water, while those of other metals are not. Note results and equations for reactions.

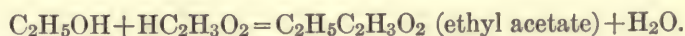
Now add dilute  $\text{HCl}$  to each of the precipitates formed. Note results and write equations for reactions. Which of the properties of carbonic acid would lead you to expect such results? Write ionic equations for reactions.

## 36. PREPARATION OF ALCOHOL

**151.** Introduce 15 g. grape sugar or dextrose ( $C_6H_{12}O_6$ ), 150 cc.  $H_2O$ , 5 cc. of Pasteur salts\* and one-eighth of a cake of compressed yeast into a 250 cc. Erlenmeyer flask and fit same with a rubber stopper and outlet as shown in Fig. 31. Into the bottle introduce clear lime water and cover this with a very thin layer of kerosene. Why? Place the apparatus in your locker for several days and then distil the solution until 25 cc. of distillate is obtained. Use a Liebig condenser. (See Fig. 9, experiment 19.) Place the receiving flask in a dish of cold water and cover it with a moist filter paper.



**152. Tests for Alcohol.** Mix 1 cc. alcohol with 1 cc. conc.  $HC_2H_3O_2$  (acetic acid) and carefully add 1 cc. conc.  $H_2SO_4$ . Let stand for a few minutes, warm slightly and note fruity odor of the vapor.



Note that the equation resembles that of a base with an acid and that ethyl acetate resembles a salt. Such organic salts are called esters.

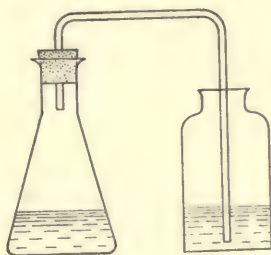


FIG. 31.

Another test. To 1 cc. of alcohol add a minute crystal of iodine. The solution should be brown. Then add  $NaOH$  solution a drop at a time until the color disappears. Shake the solution and note formation of yellow crystals of iodoform ( $CHI_3$ ). Also note odor. The reaction taking place is



\* Pasteur salts contain food necessary for the yeast plant. The solution found on the reagent shelf is made up as follows:

Potassium phosphate.....	2.00 g.
Calcium phosphate.....	0.20 g.
Magnesium sulphate.....	0.20 g.
Ammonium tartrate.....	10.00 g.
Water.....	857.60 cc.





## 37. SILICON

**153.** Place a mixture of 1 g.  $\text{SiO}_2$  (40 mesh sand) and 1.5 g. powdered magnesium in a hard glass test-tube and heat in a Bunsen flame until the appearance of the entire mass has changed. Crush the tube, pick the glass out and place the product in a 300 cc. beaker and add 100 cc. water and 25 cc. of dilute  $\text{HCl}$ . What is the substance insoluble in acid? The gas which burns at the surface of the solution? Account for the formation of the latter. Write equations for all reactions.

**154.** Prepare  $\text{SiF}_4$  (silicon tetrafluoride) by heating gently in a small lead dish (under the hood) a mixture of 1 gram sand, 2 g.  $\text{CaF}_2$  (calcium fluoride or fluorspar) and 5 cc. conc.  $\text{H}_2\text{SO}_4$ . Write equations for reactions. Hold a stirring rod, on the end of which is suspended a drop of water, in the gas and note result. Mention another method by which  $\text{SiF}_4$  may be prepared. Of what importance is the latter method in silicate rock analysis?

**155.** Heat a mixture of 0.5 g.  $\text{SiO}_2$  and 2 g.  $\text{Na}_2\text{CO}_3$  as hot as possible in a crucible placed over the flame of a Méker burner or blast lamp. When the fusion has cooled dissolve it in as little water as possible. What is the solution called? Preserve the solution for use in experiment 157.

**156.** To 50 cc. of sodium silicate (specific gravity 1.1) in a 100 cc. beaker add a small crystal of each of the following:  $\text{Co}(\text{NO}_3)_2$  (cobalt nitrate),  $\text{Cd}(\text{NO}_3)_2$  (cadmium nitrate)  $\text{CuSO}_4$ ,  $\text{FeSO}_4$ ,  $\text{NiSO}_4$  (nickel sulphate),  $\text{MnSO}_4$  (manganese sulphate) and  $\text{ZnSO}_4$ .

Note the phenomenon which takes place and account for same. Define osmosis; osmotic pressure.

**157.** To 1 cc. of sodium silicate diluted with 50 cc. of water in a 200 cc. beaker add 5 cc. conc.  $\text{HCl}$ . Note the form and color of the precipitate and write equation for reaction. Now evaporate slowly until almost dry, add 25 cc. water and 5 cc. conc.  $\text{HCl}$  and again evaporate, this time until entirely dry. What is the insoluble, white residue which remains? Of what use is this method in analytical chemistry?

Discuss the use of compounds of silicon in the manufacture of glass, cements, preservatives, etc.





## 38. BORON

**158.** Place 10 g.  $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$  (borax) in 40 cc. water. Heat until dissolved and then add 3 cc. HCl. Cool the solution and note results. Give equation for reaction. Filter off the crystals formed and place one on a dry watch glass with a drop or two of alcohol. Ignite and note results. The test for boric acid is usually performed by adding conc.  $\text{H}_2\text{SO}_4$  to the compound to form a paste. The  $\text{H}_2\text{SO}_4$  not only liberates boric acid but takes up any water present. Alcohol is then added and the vapor ignited. Give equation for the reaction between the alcohol and acidified borax solution.

**159.** Dip a piece of turmeric paper into  $\text{H}_3\text{BO}_3$  (boric acid) solution containing some HCl, or a borate made acid by HCl. Note color. Dry the paper by warming above a Bunsen flame. Note color again. Now moisten the same paper with  $\text{NH}_4\text{OH}$  and note color. Take a fresh piece of turmeric paper and moisten with  $\text{NH}_4\text{OH}$ . Compare results with above.

**160.** Place 10 g. borax in a 250 cc. flask. Add 50 cc. water and 5 cc. conc.  $\text{H}_2\text{SO}_4$ . Fit the flask with a one-hole stopper and delivery tube leading into a test-tube of distilled water. Heat the flask to boiling but be careful that the liquid does not splash against the outlet tube. After boiling five minutes test the contents of the tube as in 159. How do you account for the presence of  $\text{H}_3\text{BO}_3$ ?

**161.** Try the effect of a solution of  $\text{Na}_2\text{SiO}_3$  (sodium silicate) and also a solution of  $\text{Na}_2\text{B}_4\text{O}_7$  (borax) on dilute solution of each of the following:  $\text{ZnSO}_4$ ,  $\text{CuSO}_4$ ,  $\text{Co}(\text{NO}_3)_2$ ,  $\text{Ni}(\text{NO}_3)_2$ ,  $\text{MnSO}_4$ . Note the nature of the precipitates and equations for reactions. Also note that most silicates and borates are water insoluble.

**162.** Calculate the weight of boric acid obtainable from 100 g. borax containing maximum water of crystallization. Write the equation first, then the ratio and then work your problems using the following atomic weights: Na = 23, B = 11, O = 16, H = 1.008.



## 39. SODIUM

**163. Preparation of Sodium Carbonate.** (Principle of the Solvay Process.)

Into a test-tube introduce a saturated solution of salt. Pass  $\text{NH}_3$  into this until the solution is saturated with the gas. The ammonia may be generated by boiling 50 cc. of concentrated ammonium hydroxide solution placed in a small Erlenmeyer flask fitted with a delivery tube which extends to the bottom of the test-tube. Then prepare a  $\text{CO}_2$  generator by placing marble in a bottle and adding dilute  $\text{HCl}$ . Fit the bottle with a delivery tube which extends to the bottom of the test-tube and continue the action of  $\text{CO}_2$  until crystals cease forming in the test-tube. Then filter off the crystals and transfer them (by scraping from the paper) to a clock glass. Heat gently until dry. The mass consists of  $\text{NaHCO}_3$ . In the commercial process these crystals are heated until  $\text{Na}_2\text{CO}_3$  forms. To prove  $\text{CO}_2$  formation through the decomposition, heat some of the dry crystals in a test-tube fitted with a delivery tube which dips into clear  $\text{Ca}(\text{OH})_2$  solution. Give equations for laboratory reactions and also for all of those taking place in the Solvay Process as worked on a large scale.

**164. Tests for Carbonates and Bicarbonates.** Into a test-tube introduce  $\text{Na}_2\text{CO}_3$  solution and dilute  $\text{HCl}$ . Also try the action of  $\text{HCl}$  on  $\text{NaHCO}_3$  solution. Note results and write equations for reactions.

To a dilute solution of  $\text{Na}_2\text{CO}_3$  add  $\text{MgSO}_4$  solution. Also try the action of  $\text{Ba}(\text{OH})_2$  solution. Now add  $\text{MgSO}_4$  solution to a dilute solution of  $\text{NaHCO}_3$ . Write equations for reactions.

How would you test for the presence of carbonates and bicarbonates? How distinguish between them?





## 40. SODIUM

**165.** Prepare 100 cc. of a cold saturated solution of common salt by shaking the salt with water until no more goes into solution. Filter. Generate HCl by heating salt with conc. sulphuric acid in a generating flask. Connect the outlet tube with a funnel which rests immediately over the surface of the saturated salt solution in a beaker without touching the solution and continue generating HCl (*in the hood*) until a precipitate ceases to form in the beaker. Why use a funnel instead of a narrow tube? Filter the salt by placing a crucible lid, handle up, in a funnel and allowing the salt crystals to collect on its surface. On what principle does the precipitation of the salt depend? Show by a mathematical formula and equations why NaCl is precipitated. What are the impurities? Why do they not come down with the sodium chloride?

Dissolve a few crystals in a little water. Dip a platinum wire into the solution and heat it in a clear blue flame. Note results. View the flame through methyl blue solution in a potassioscope. Note results.

**166. Preparation of Sodium Hydroxide.**

**Warning.** Caustic alkalies attack the skin and clothing. To neutralize alkali burns apply boric acid or olive oil.

To 10 grams of sodium carbonate dissolved in 100 cc. of water in a 6 in. porcelain dish add 20 per cent more  $\text{Ca(OH)}_2$  by weight than is necessary to complete the reaction. Place the dish and its contents on an iron stand and heat gently until a little of the clear liquid fails to give the gas evolution reaction characteristic of carbonates when treated with HCl. Then filter through asbestos or glass wool. Why not through paper? The asbestos or glass wool may be supported on a glass rod with a flattened top, placed in the stem of a funnel, and the solution run through several times until a clear liquid is obtained. Apply the HCl test for carbonates to a little of the original sodium carbonate used, to a little of the clear liquid obtained after filtration, to some of the  $\text{Ca(OH)}_2$  and to a portion of the residue remaining after filtration. From the facts gathered through these tests construct an equation for the reaction.

Add a little of the filtered solution to a dilute solution of each of the following and write equations for reactions:  $\text{MgSO}_4$ ;  $\text{FeCl}_3$ ;  $\text{Al}_2(\text{SO}_4)_3$ ;  $\text{Cr}_2(\text{SO}_4)_3$ ;  $\text{Ni(NO}_3)_2$ .

Sulphates, chlorides, nitrates, etc., may be prepared by adding the respective acids to sodium carbonate until it is completely decomposed and crystallizing from the solutions obtained.

**167. Tests.** The yellow flame together with the precipitate obtained by adding potassium pyroantimonate ( $\text{K}_2\text{H}_2\text{Sb}_2\text{O}_7$ ) serves to indicate the presence of sodium salts. Place a little sodium chloride on a watch crystal and add a drop of  $\text{K}_2\text{H}_2\text{Sb}_2\text{O}_7$ . Stir with a rod, note result and write the equation for the reaction. Only potassium in the compound is replaced by sodium. Prepare the structural formula of the reagent on the basis of experience acquired in the study of a relative of Sb.





## 41. POTASSIUM, LITHIUM, AMMONIUM

**168. Potassium.** Tests. To a little KCl on a watch glass add a drop or two of  $\text{H}_2\text{PtCl}_6$  (chloroplatinic acid). If no precipitate forms add a few drops of  $\text{C}_2\text{H}_5\text{OH}$  (ethyl alcohol). Filter on a very small paper (5 cm. diam.), scrape the precipitate from the paper and heat it on a porcelain crucible lid. Note results. Write the equation for the reaction between KCl and  $\text{H}_2\text{PtCl}_6$ . Examine the precipitate under a microscope by placing a drop of the solution containing it on a watch glass. Have the instructor show you how to use the microscope. Prepare a drawing of a number of characteristic crystals.

Make flame test using KCl solution. Prepare a mixture of KCl and NaCl and repeat flame test. Now examine the flame through methyl blue solution (potassioscope). Note results.

**169. Ammonium.** Repeat the experiment with  $\text{H}_2\text{PtCl}_6$ , using  $\text{NH}_4\text{Cl}$  instead of KCl. Also try the experiment with NaCl and compare the three results. Write the equation for the  $\text{NH}_4\text{Cl}$  reaction.

Place some  $\text{NH}_4\text{Cl}$  solution in a very small beaker and add NaOH solution. Cover the beaker with a clean watch glass to the under surface of which a short piece of red litmus paper has been affixed at the center by moistening with water. Now heat the contents of the beaker, being careful that the liquid does not splash against the watch glass. As soon as the paper has turned color notice the odor of the evolved gas. Hold the moist stopper from a conc. HCl bottle over the beaker. Note results and write equations for reactions.

**170. Lithium.** Try the flame test, using LiCl solution. Note results.

**171. Analysis.** Ask your instructor for a sample for analysis and report on Na, K,  $\text{NH}_4$ , or Li ion detected in the compounds, giving reasons for your conclusions. This report is to be included in your notes. Place the number of your sample at the beginning of the report.



## 42. BARIUM, STRONTIUM, CALCIUM

**172. Reactions.** To a little dilute  $\text{BaCl}_2$ ,  $\text{SrCl}_2$  and  $\text{CaCl}_2$  \* in separate test-tubes, add a few drops of  $(\text{NH}_4)_2\text{CO}_3$  and warm. Then add some dilute  $\text{HC}_2\text{H}_3\text{O}_2$  (acetic acid) to a part of each precipitate and warm. Also try the action of dilute  $\text{HCl}$  on the precipitate. Note results and write equations for reactions.

**173.** To each of the dilute chlorides add a few drops of  $\text{K}_2\text{CrO}_4$  (potassium chromate) and warm. Then add dilute  $\text{HC}_2\text{H}_3\text{O}_2$  to a part of each precipitate and warm. Also try the action of dilute  $\text{HCl}$  on the precipitates. Note results and write equations for reactions.

**174.** To each of the dilute chlorides add 5 cc.  $(\text{NH}_4)_2\text{SO}_4$  and boil. Repeat using a little dilute  $\text{H}_2\text{SO}_4$  instead. Note results and equations for reactions.

**175.** To each of the dilute chlorides add  $\text{NH}_4\text{OH}$  and  $(\text{NH}_4)_2\text{C}_2\text{O}_4$  (ammonium oxalate). Try the action of dilute  $\text{HCl}$  on the precipitates. Note results and equations for reactions.

**176.** Try the flame test on each of the chlorides.

**177. Separation and Tests.** Prepare a mixture of 5 cc. each of  $\text{BaCl}_2$ ,  $\text{SrCl}_2$  and  $\text{CaCl}_2$  solution (reagent). Dilute to 100 cc. in a 200 cc. beaker, render alkaline with  $\text{NH}_4\text{OH}$  and add  $(\text{NH}_4)_2\text{CO}_3$  solution until precipitation is complete.† Warm the solution and let the precipitate settle. Add a little  $(\text{NH}_4)_2\text{CO}_3$  to the clear liquid to see if all Ba, Sr and Ca were precipitated. Filter and wash the precipitate twice with hot distilled water. Discard the filtrate (solution which has run through) and dissolve the precipitate on the filter with as little dilute, hot  $\text{HC}_2\text{H}_3\text{O}_2$  as possible, running the solution into a clean beaker.

Heat the solution to boiling and add  $\text{K}_2\text{CrO}_4$ , a little at a time until precipitation is complete.† Filter, saving the solution and test the precipitate by making the flame test on a little dissolved in  $\text{HCl}$ . To the filtrate add an excess of  $(\text{NH}_4)_2\text{SO}_4$  solution and boil.† Filter, saving the solution, and make the flame test on the precipitate after moistening it with a few drops of  $\text{HCl}$ . To the filtrate add  $(\text{NH}_4)_2\text{C}_2\text{O}_4$  and filter. Treat a little of the precipitate with  $\text{HCl}$  and make flame test. Write equations for all reactions involved.

**178.** To a little dilute  $\text{BaCl}_2$  solution add clear  $\text{SrSO}_4$  solution. To a little dilute  $\text{BaCl}_2$  and  $\text{SrCl}_2$  solution, in separate test tubes, add clear  $\text{CaSO}_4$  solution. Note results with equations for reactions. How do you account for the results obtained?

\* Prepared by diluting 5 cc. of the shelf reagent (a normal solution) with water to 25 cc.

† Always test the filtrate with a little more of the reagent to see if precipitation is complete. Any barium compound going through the filter paper interferes with strontium and calcium tests, and strontium going through will interfere with the calcium test.





### 43. ANALYSIS OF WATER

**179.** Test for the chlorine ion in tap water by placing some in a *clean* beaker and adding a few drops of  $\text{HNO}_3$  and  $\text{AgNO}_3$ . If a precipitate fails to appear let the solution stand for a while. Repeat the experiment, making the test on distilled water.

**180.** Test for the sulphate ion in another portion of each by adding a few drops of  $\text{HCl}$  and  $\text{BaCl}_2$  solution. Let stand if necessary.

**181.** Test for Fe by acidifying with  $\text{HCl}$  and adding  $\text{K}_4\text{Fe}(\text{CN})_6$  (potassium ferrocyanide) or  $\text{KCNS}$  (potassium thiocyanate).

**182. Hardness.** Into a clean 250 cc. glass stoppered bottle introduce 100 cc. tap water and add soap solution, 5 drops at a time, shaking vigorously after each addition until the bottle, lying on its side, shows an unbroken lather after two minutes. From the  $\text{CaCO}_3$  value on the soap bottle and the number of cubic centimeters used calculate the parts per million. This gives total hardness.

Now boil 100 cc. water, filter into the bottle, cool and repeat the experiment. The first value minus the last gives temporary hardness.

Repeat on cold distilled water.

To what is temporary hardness due? Permanent hardness?

*In Quantitative Analysis* temporary and permanent hardness are now determined by titration with  $\text{N}/50$  acid and alkali solutions using alizarine and methyl orange as indicators. The method is somewhat long for use here.

How would you treat water to overcome temporary hardness? Permanent hardness? Give equations for reactions supposing calcium salts to be present.





## 44. COPPER

Prepare a  $\text{CuSO}_4$  solution by diluting 5 cc. of the shelf reagent to 25 cc. with water, using a little of this in a test-tube for reactions. Remember that a reaction works just as well with a small quantity of material which costs less than larger quantity.

183. Try the action of dilute and concentrated  $\text{HCl}$ ,  $\text{HNO}_3$ , and  $\text{H}_2\text{SO}_4$  on a bit of copper, using test-tubes. If no action takes place in the cold, apply heat. Give equations for reactions.

184. To a dilute solution of  $\text{CuSO}_4$  add a few drops of  $\text{NaOH}$ . Boil. Note results in cold and hot solution and write equations for reactions. Repeat the experiment, using  $\text{NH}_4\text{OH}$ , a drop at first and then an excess. Note results and write ionic equations for reactions.

185. To a  $\text{CuSO}_4$  solution slightly acid with  $\text{HCl}$ , add a little  $\text{H}_2\text{S}$  water; to another tube of unacidified solution add a drop of  $(\text{NH}_4)_2\text{S}$ . Note results and equations for reactions.

186. Dip a clean Pt wire into  $\text{CuSO}_4$  solution and note color imparted to flame.

187. Prepare some cuprous oxide,  $\text{Cu}_2\text{O}$ , by adding a little glucose solution to a boiling Fehling solution. The Fehling solution is ready for use and was prepared by dissolving 35 g.  $\text{CuSO}_4$  in 500 cc. water (solution A); and 170 g.  $\text{NaKC}_4\text{H}_4\text{O}_6$  (sodium potassium tartrate, or Rochelle salt) to 80 g.  $\text{KOH}$  in 500 cc. water (solution B). As a rule equal quantities of these solutions are mixed just before using. In this case they are already mixed for use. The solution serves for the detection and determination of reducing sugars in honey and other sugar-bearing foods; also for the detection of sugar in urine. Compare  $\text{Cu}_2\text{O}$  with  $\text{CuO}$ .

188. To some  $\text{CuSO}_4$  solution in test-tubes add small bits of  $\text{Zn}$ ,  $\text{Al}$  and  $\text{Fe}$ , noting results, and equations for reactions. How do you account for the results?

The student is asked to recall the ease with which  $\text{CuO}$  was reduced to  $\text{Cu}$  by  $\text{H}_2$  in an earlier experiment. The metal may also be obtained by heating  $\text{CuO}$  with  $\text{C}$ .

189. To some dilute  $\text{CuSO}_4$  solution add a few drops of  $\text{K}_4\text{Fe}(\text{CN})_6$  (potassium ferrocyanide) solution. Note results and equations for reactions. This test will detect 1 part of  $\text{Cu}$  in 200,000 of solution.



## 45. SILVER AND GOLD

Save all silver precipitates for experiment 198. Dilute 5 cc.  $\text{AgNO}_3$  solution from reagent bottle to 25 cc. and use a little of this for each test. Remember that a reaction works just as well with a small quantity of the material and costs less than a larger quantity.

**190.** To a little  $\text{AgNO}_3$  solution in a test-tube add a few drops of dilute  $\text{HCl}$ . Note results. Expose the precipitate to sunlight and note change. Add  $\text{NH}_4\text{OH}$  and again note effect. Add  $\text{HNO}_3$  and record results. Write equations for all reactions. These reactions together with the formation of red  $\text{Ag}_2\text{CrO}_4$  serve to identify the silver ion.

**191.** To separate portions add a few drops of  $\text{KBr}$  and  $\text{KI}$  and note results with equations for reactions.

**192.** To a little  $\text{AgNO}_3$  solution add a few drops of  $\text{NaOH}$  solution. Note results and write equation for reaction.

**193.** Try the effect of  $\text{Na}_2\text{CO}_3$  solution giving equations for reactions.

**194.** Try the action of a few drops of  $\text{KCN}$  (potassium cyanide). This material is exceedingly poisonous. Try effect of an excess on the reaction. Note results and write equations for reactions.

**195.** Try the action of  $\text{H}_2\text{S}$  on a solution of  $\text{AgNO}_3$ , noting results and giving equations for reactions.

**196.** Add a few drops of  $\text{K}_2\text{CrO}_4$  (potassium chromate) to  $\text{AgNO}_3$  solution. Add dilute  $\text{HNO}_3$  to the precipitate. Note results and equations for reactions. Now add to another portion,  $\text{NaCl}$  solution in excess and then  $\text{K}_2\text{CrO}_4$ . Why no chromate precipitate this time?

**197.** Place a bit of  $\text{Zn}$  in a dilute solution of  $\text{AgNO}_3$  in a test-tube and note the result with equation for reaction. How would you separate the excess  $\text{Zn}$  from the  $\text{Ag}$ ?

**198.** Mix all your silver precipitates with pulverized charcoal and  $\text{Na}_2\text{CO}_3$  and heat in the reducing flame of your blowpipe in a cavity in charcoal. Flatten the silver button, cut it into several pieces and try the action of dilute  $\text{HNO}_3$  and  $\text{H}_2\text{SO}_4$  respectively, giving equations for all reactions.

**199.** To a little dilute  $\text{AuCl}_3$  (gold chloride) solution add a drop of  $\text{SnCl}_2$  (stannous chloride). The precipitate of gold is known as "Purple of Cassius" and serves as a test for  $\text{Au}$ .

**200.** To a little undiluted  $\text{AuCl}_3$  add a few crystals of  $\text{H}_2\text{C}_2\text{O}_4$  and boil. Note color of precipitate and solution (the latter by transmitted light). Boil until the precipitate settles transfer it to charcoal and heat in the blowpipe flame until a globule forms.

State Faraday's Law. What is meant by "Electromotive Series"? Account for certain reactions under  $\text{Cu}$  and  $\text{Ag}$  by the latter.





#### 46. COMPLEX IONS, COMMON ION EFFECT, HYDROLYSIS, EFFECT OF VOLATILIZATION

**Warning.** Potassium cyanide is exceedingly poisonous. Do not add acid to cyanides or boil acid solutions.

**201.** To a little  $\text{AgNO}_3$  solution add a few drops of  $\text{NaCl}$  solution. Now add ammonium hydroxide. Give ionic equations for reactions and explain same. Also explain by the use of the ion product constant formula.

To a little  $\text{CuSO}_4$  solution add a few drops of  $\text{NH}_4\text{OH}$ . Then add  $\text{NH}_4\text{OH}$  in excess. Explain and give ionic equations for reactions.

Add several drops of  $\text{AgNO}_3$  solution to distilled water. Add a drop of  $\text{NaCl}$ , note the result and write equation for reaction. Into another test-tube containing some dilute  $\text{AgNO}_3$  solution introduce  $\text{KCN}$  (potassium cyanide) solution a drop at a time until the precipitate formed redissolves. Write equations for reactions. Now add  $\text{NaCl}$  solution. Why does  $\text{AgCl}$  fail to precipitate?

To a little  $\text{FeCl}_3$  (ferric chloride) solution add a few drops of  $\text{K}_4\text{Fe}(\text{CN})_6$  (potassium ferrocyanide) solution. What is the precipitate? Write ionic equation for reaction. Repeat the experiment, using  $\text{CuSO}_4$ ,  $\text{Ni}(\text{NO}_3)_2$  and  $\text{ZnSO}_4$  respectively, instead of  $\text{FeCl}_3$ . What is a complex ion? List the complex ions found in each of the above reactions. Note that in some cases the metallic elements form a complex cation and in others the anion.

**202.** Prepare about 10 cc. each of saturated solutions of  $\text{BaCl}_2$  and  $\text{NaCl}$  in test-tubes. To 5 cc. of the  $\text{BaCl}_2$  solution add concentrated  $\text{HCl}$ . Now add concentrated  $\text{HCl}$  to 5 cc. of the  $\text{NaCl}$  solution. Add the remaining 5 cc. of  $\text{NaCl}$  solution to the remaining 5 cc. of  $\text{BaCl}_2$  solution. What are the precipitates in each case? Account for their formation by use of the ion product constant formula.

**203.** To a solution of  $\text{Na}_2\text{CO}_3$  in a test-tube add a few drops of  $\text{HCl}$  and note results. Write the complete set of ionic and molecular equations.

To a strong  $\text{NaCl}$  solution add conc.  $\text{H}_2\text{SO}_4$  a drop at a time and note results. Write the complete set of ionic and molecular equations. Account for the reactions by using the ion product constant formula.

**204.** Test with litmus paper each of the following solutions:  $\text{NaCl}$ ,  $\text{FeCl}_3$ ,  $\text{Na}_2\text{CO}_3$ ,  $\text{NaHCO}_3$ ,  $\text{NaC}_2\text{H}_3\text{O}_2$  and  $\text{CuSO}_4$ .

Explain the results in each case. In general which salts are hydrolyzed? Which class gives acid reactions? Which neutral? Which alkaline? Write ionic equations to account for above actions.





## 47. MAGNESIUM, ZINC, CADMIUM, MERCURY

**205. Magnesium.** Test for magnesium by adding  $\text{NH}_4\text{OH}$ ,  $\text{NH}_4\text{Cl}$  and  $\text{Na}_2\text{HPO}_4$  to a dilute solution of  $\text{MgSO}_4$ . Substitute  $\text{Na}_2\text{CO}_3$  for  $\text{Na}_2\text{HPO}_4$ ;  $\text{NaOH}$  for  $\text{Na}_2\text{HPO}_4$ . Also try the action of  $\text{NaOH}$  in absence of ammonium compounds.

**206. Zinc.** Test for zinc by adding  $\text{H}_2\text{S}$  water to a dilute neutral or slightly alkaline solution of  $\text{ZnSO}_4$ . Try the solubility of the precipitate in  $\text{HCl}$ . Give equations for all reactions.

Heat a little  $\text{ZnO}$  on charcoal in the oxidizing blowpipe flame. Note the color while hot and cold.

Now moisten the residue with a drop of  $\text{Co}(\text{NO}_3)_2$  (cobalt nitrate) and reheat for some time. Note results.

**207 Cadmium.** Add  $\text{H}_2\text{S}$  water to a dilute slightly acid solution of  $\text{CdCl}_2$ . Add a little  $\text{HCl}$  to the precipitate. Note results and write equations for reactions.

Heat a  $\text{Cd}$  salt in the oxidizing flame on charcoal. Note the color of the residue. What has formed?

**208. Mercury.**

**Warning.** Do not throw mercury compounds in the sinks but empty the test-tubes into jars provided for the purpose. Why? Be careful in handling  $\text{Hg}$  compounds. Why?

Test for  $\text{Hg}$  in a little  $\text{HgCl}_2$  (mercuric chloride) solution by introducing a strip of  $\text{Cu}$  and subsequently rubbing it with a cloth. Give equation for reaction.

To a little dilute  $\text{HgCl}_2$  solution add a drop of  $\text{SnCl}_2$  (stannous chloride). Then add a little more. Note results and equations for reactions.

To a little  $\text{HgNO}_3$  (mercurous nitrate) add  $\text{HCl}$ . Treat the precipitate with  $\text{NH}_4\text{OH}$ . Note results with equations for reactions, and compare with similar treatment of  $\text{AgNO}_3$ .

To a little  $\text{HgNO}_3$  add a drop of  $\text{KI}$ . Next try the reagent on a little  $\text{HgCl}_2$  solution. Note results and write equations for reactions.



## 48. ALUMINIUM, LEAD, TIN

**209. Aluminium Tests.** To a dilute solution of  $\text{Al}_2(\text{SO}_4)_3$  in a test-tube add several drops of  $\text{NH}_4\text{OH}$ . Note the color and form of precipitate together with equation for reaction. Filter and note the form of the mass on the paper. Place a little of the precipitate on charcoal. Moisten it with  $\text{Co}(\text{NO}_3)_2$  and heat strongly in the blowpipe flame. Note results. This combination of reactions serves for the detection of aluminium.

**210.** Into separate test-tubes introduce small quantities of dilute  $\text{Al}_2(\text{SO}_4)_3$ ,  $\text{ZnSO}_4$ ,  $\text{CuSO}_4$  and  $\text{FeCl}_3$ . To each add a drop of  $\text{NaOH}$  solution and note results. Then add an excess of  $\text{NaOH}$  and note results in the cold and on boiling. Repeat the original precipitation in fresh portions and note the effect of adding an excess of  $\text{HCl}$  subsequently boiling if necessary. Also try the action of  $\text{HCl}$  on precipitates which were redissolved by  $\text{NaOH}$ . Add the acid dropwise in these cases. Note results and equations for all reactions. What name is applied to a substance whose hydroxide dissolves in both acids and alkalies? How do the metals usually react with  $\text{NaOH}$ ?

**211. Tin.** To a little  $\text{SnCl}_2$  (stannous chloride) in water acidified with  $\text{HCl}$  add  $\text{H}_2\text{S}$  water, note results and write equations for reactions. Try same test on  $\text{SnCl}_4$  (stannic chloride). Compare with zinc reactions.

Recall the action of  $\text{SnCl}_2$  on  $\text{AuCl}_3$  and  $\text{HgCl}_2$ . What is such a substance called?

**212. Reduction of Oxides.** Mix a little  $\text{PbO}$  with charcoal and heat on charcoal in the reducing blowpipe flame. Repeat using  $\text{SnO}_2$ . Note results with equations for reactions.

**213. Tests for Lead.** Try the action of dilute  $\text{H}_2\text{SO}_4$  on  $\text{Pb}(\text{NO}_3)_2$  solution. Heat the mixture. Do you notice any change? Give equation for reaction.

Try action of dilute  $\text{HCl}$  on  $\text{Pb}(\text{NO}_3)_2$  solution. Heat this mixture and note results.

Try the action of  $\text{H}_2\text{S}$  water on an acidified solution of  $\text{Pb}(\text{NO}_3)_2$ . Note result and equation for reaction.

Try the action of  $\text{K}_2\text{CrO}_4$  on  $\text{Pb}(\text{NO}_3)_2$  solution.

Write equations for above reactions.

These four tests serve to identify lead.

Recall the action of  $\text{HCl}$  on  $\text{AgNO}_3$  and the solubility of the precipitate in  $\text{NH}_4\text{OH}$ . Also that it was insoluble in hot water. Further the action of dilute  $\text{HCl}$  on  $\text{HgNO}_3$ . What effect did  $\text{NH}_4\text{OH}$  have on the precipitate?

From the above facts suggest a method for the separation of silver, mercury (valence 1) and lead in a mixture of their nitrates.





## 49. PREPARATION OF ALUM FROM CRYOLITE.\*

**214.** Slake 12 g. quicklime and then mix in a 6 in. porcelain dish with 70 cc. of water to make milk of lime. Stir into this 13 g. of finely powdered cryolite, and heat to boiling while stirring constantly. Continue boiling for an hour, adding water to replace that lost by evaporation and stirring sufficiently to avoid spattering. At the end of that time add a part of 400 cc. of boiling water to the thick mass in the dish and transfer it, together with the rest of the hot water, to a one-liter Erlenmeyer flask, and set aside to settle until the next period. The sludge should have settled so as to occupy not more than one-fifth of the volume of the liquid. Siphon off as much clear liquid as possible without drawing over any of the precipitate. Then add 400 cc. more of hot water to the flask, stir and again let settle, and draw off the clear liquor. The residue in the flask may be thrown away. Combine all the solution in a large flask and pass in carbon dioxide (*hood*) from a generator until all of the alumina is precipitated. Test to see if this is accomplished at the end of one-half hour by stopping the carbon dioxide stream and letting the precipitate settle enough to pour off a little clear liquor into a beaker. Pass carbon dioxide into this for a few minutes; if no precipitate occurs it shows that all of the alumina has already been removed from the solution. If a precipitate does appear, the treatment of the entire solution with carbon dioxide must be continued until all the alumina is thrown out. Then let the solution settle until the precipitate occupies less than one-sixth of the entire volume. Siphon off the clear liquid and evaporate it to dryness in a porcelain dish. Powder and preserve the sodium carbonate so obtained. Stir up the precipitate left in the flask with 400 cc. of hot water; let settle, and siphon off and discard the clear liquid, since it will not contain sufficient sodium carbonate to pay for its evaporation. To the suspension of aluminium hydroxide left in the flask add 7 cc. of concentrated sulphuric acid, and warm, if necessary, to effect complete solution. Add 11 grams of potassium sulphate, and warm until dissolved. The solution should now be perfectly clear; if not, filter. If the volume exceeds 100 cc. evaporate to that bulk, and while still hot transfer it to the crystallizing dish (a 6 in. porcelain dish will answer). When cooled to 55–50° C. drop eight to ten very small alum crystals into the solution, cover immediately with a cardboard, wrap the whole in a clean cloth and set where it will not be disturbed until the next exercise. Remove the few large crystals formed and preserve them.

Evaporate the mother liquor to not quite one-half its volume (say nine-sixteenths, and set this to crystallize exactly in the same manner as before. Add the crystals so obtained to the first lot. Write equations for all reactions.

Of what does the insoluble residue consist which remains after boiling the cryolite with milk of lime? Write ionic equation for solution of  $\text{Al}(\text{OH})_3$  in  $\text{H}_2\text{SO}_4$ ; in  $\text{NaOH}$ . Compare its strength as an acid and as a base with that of other common electrolytes. Define amphoteric electrolyte.

**215.** Add a solution of sodium hydroxide drop by drop, to a few cc. of a solution of aluminium chloride, continuing until a considerable amount is added after the first effect is observed. Preserve the contents of the tube.

Repeat, using a solution of ammonium hydroxide instead of one of sodium hydroxide.

To the first tube add a solution of ammonium chloride and note results. Account for all results on the basis of ionization.

\* This method with slight modification, is taken from Blanchard's *Synthetic Inorganic Chemistry*.





## 50. ARSENIC, ANTIMONY, BISMUTH

**Warning.** Arsenic compounds are exceedingly poisonous. If vapors are given off work in the hood.

**216.** Into each of three 5 mm. tubes, 15 cm. long and closed at one end, place a particle of arsenic, antimony and bismuth about the size of an ordinary pin head. Heat the tubes at the bottom and observe any change taking place at the cool end. What name is applied to this phenomenon?

Repeat the experiment using a very small quantity of a mixture of each of the oxides of arsenic, antimony and bismuth mixed with some pulverized charcoal. Also try the effect of heating the oxides alone. Note results. Repeat heating a little dry  $\text{NH}_4\text{Cl}$  alone. An iodine crystal.

**217.** Try the effect of a little concentrated  $\text{HCl}$  on each of the oxides and metals. Repeat using concentrated  $\text{HNO}_3$ . Try again with concentrated  $\text{H}_2\text{SO}_4$ . Give equations for any reactions which take place.

**218.** To a dilute solution of  $\text{K}_3\text{AsO}_3$  (potassium arsenite), the potassium salt of arsenious acid ( $\text{As}_2\text{O}_3 + 3\text{H}_2\text{O}$  or  $\text{H}_3\text{AsO}_3$ ) add a drop of  $\text{AgNO}_3$ . In another test-tube try the action of  $\text{CuSO}_4$ . Repeat these tests using potassium arsenate ( $\text{K}_3\text{AsO}_4$  the potassium salt of arsenic acid). Note results and write equations for reactions.

**219.** To a solution of  $\text{K}_3\text{AsO}_3$  add a little conc.  $\text{HNO}_3$  and boil. Neutralize with dilute  $\text{NaOH}$  and then make slightly acid with  $\text{HC}_2\text{H}_3\text{O}_2$ . Try the action of  $\text{AgNO}_3$  and of  $\text{CuSO}_4$ . What has happened to the arsenious acid? Give equation for reaction.

**220.** To a little  $\text{K}_3\text{AsO}_3$  add a drop of *dilute*  $\text{KMnO}_4$  solution and heat. Explain the change and write equation for reaction.

**221.** Pass a little  $\text{H}_2\text{S}$  gas through a solution of  $\text{K}_3\text{AsO}_3$ , another of  $\text{SbCl}_3$  and another of  $\text{BiCl}_3$ . Note results and account for conditions found. Now add a few drops of conc.  $\text{HCl}$  to each of the solutions which were not precipitated and repeat the  $\text{H}_2\text{S}$  treatment. Give equations for reactions. Define precipitate; colloid; molecular solution. Give a rough method for distinguishing between them.

**222.** To another set of solutions like 221 add a drop or two of  $(\text{NH}_4)_2\text{S}$ . Then add  $\text{HCl}$  (dilute) a drop at a time until a precipitate forms. Again add  $(\text{NH}_4)_2\text{S}$  and note effect on each of the precipitates. Give equations for the precipitation and re-solution. What name is applied to the compounds obtained through re-solution?

**223** To strong solutions of antimony ch'loride and bismuth chloride in test-tubes add water a drop at a time noting results. What is the action of the water called? Give equations for reactions. If two solutions were precipitated by water and you wanted to distinguish between Sb and Bi how would you proceed?

**224.** Heat a little  $\text{Bi}_2\text{O}_3$  in a cavity on charcoal, using the reducing flame of a blowpipe

**225.** Derive the formula of the oxide produced by the burning of 2.5 grams of phosphorus in oxygen to a final weight of 5.7 grams.

$$\text{P} = 31.04, \text{O} = 16 \text{ (Hale).}$$

**226.** Derive the formula of a nitrate, 19.7 grams of which was prepared from 10.4 grams of bismuth.  $\text{Bi} = 208, \text{N} = 14.01$  (Hale).



## 51 VANADIUM, CHROMIUM, MOLYBDENUM, TUNGSTEN, URANIUM

**227. Test for vanadium.** To a few drops of  $\text{H}_3\text{VO}_4$  (vanadic acid) diluted with water in a test-tube and acidified with  $\text{HCl}$  add a little  $\text{H}_2\text{O}_2$ . Note results.

**228. Chromium.** (a) To a dilute solution of  $\text{Cr}_2(\text{SO}_4)_3$  in separate test-tubes add a drop of each of the following reagents, noting results and equations for reactions:  $\text{NH}_4\text{OH}$ ,  $\text{NaOH}$ ,  $\text{Na}_2\text{CO}_3$ ,  $(\text{NH}_4)_2\text{S}$ . Filter the last two precipitates, wash with hot water and treat with a little dilute  $\text{HCl}$ . Were carbonates and sulphides formed? If not, why not?

(b) To another portion of  $\text{Cr}_2(\text{SO}_4)_3$  solution add a little dry  $\text{Na}_2\text{O}_2$  (sodium peroxide) and boil. Acidify with  $\text{HC}_2\text{H}_3\text{O}_2$  and add a drop of  $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$ . Write equations for reactions.

**229.** To a dilute solution of  $\text{Na}_2\text{CrO}_4$  (sodium chromate) in separate test-tubes add a drop of each of the following reagents and note results with equations for reactions.  $\text{BaCl}_2$ ,  $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$ ,  $\text{AgNO}_3$ . Repeat, using  $\text{Na}_2\text{Cr}_2\text{O}_7$  (sodium dichromate).

**230.** To some dilute  $\text{Na}_2\text{Cr}_2\text{O}_7$  acidified with  $\text{HCl}$  add  $\text{C}_2\text{H}_5\text{OH}$  (ethyl alcohol) and boil. Notice the apple-like odor of  $\text{C}_2\text{H}_4\text{O}$  (aldehyde) which forms. Write equation for reaction. To the green solution formed add  $\text{NaOH}$  and compare results with 228.

**231.** To 1 cc. of a saturated solution of  $\text{Na}_2\text{Cr}_2\text{O}_7$  in a test-tube add conc.  $\text{H}_2\text{SO}_4$  a drop at a time, until a precipitate forms. Note result and write equation for reaction. Pour off the clear liquid into the sink letting the water run (handle with care) and, by means of a glass rod, transfer some of the crystals to a dry test-tube. Heat and note results with the equation for the reaction.

**232.** To a bead of borax or microcosmic salt add a speck of a chromium compound and heat in the blowpipe flame. Note color.

This and a fusion with  $\text{Na}_2\text{O}_2$  followed by dilution with water, acidification with  $\text{HC}_2\text{H}_3\text{O}_2$  and formation of a yellow precipitate with  $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$  serves to identify chromium.

**233. Test for Molybdenum.** To a few drops of a solution of molybdenum add a little  $\text{NH}_4\text{OH}$ , then acidify with dilute nitric acid and add a drop of  $\text{Na}_2\text{HPO}_4$  solution. Boil and note results. The formula usually assigned to the precipitate is  $(\text{NH}_4)_3\text{PO}_4 \cdot 11\text{MoO}_3 \cdot 6\text{H}_2\text{O}$ .

**234. Test for Tungsten.** To a speck of a tungsten compound add a little  $\text{NaOH}$  solution and boil. Acidify with dilute  $\text{HCl}$ , add a little zinc and boil. Note results. (Insoluble compounds are fused with  $\text{NaOH}$  then treated with  $\text{HCl}$  and  $\text{Zn}$ .)

**235. Tests for Uranium.** To a dilute solution of a uranium salt add  $\text{HCl}$  and a drop of  $\text{K}_4\text{Fe}(\text{CN})_6$ . Note results. Add a minute speck of uranium compound to a bead of  $\text{Na}(\text{NH}_4)\text{HPO}_4$  (microcosmic salt) and note color while hot and on cooling. Reheat and note color while bead warms up.





## 52. MANGANESE

**236.** To a little dilute  $\text{MnSO}_4$  add a few drops of  $\text{NaOH}$ . Note the color of the precipitate and examine it from time to time. How do you account for the change?

**237.** Try the action of a drop of  $(\text{NH}_4)_2\text{S}$  on  $\text{MnSO}_4$ . Note result and write equation for reaction.

**238.** To a little dilute  $\text{MnSO}_4$  solution add some  $\text{PbO}_2$  and  $\text{HNO}_3$ . Boil. Let the precipitate settle. Note results. What has formed? This reaction will not work in the presence of chlorides. Why?

**239.** To a very dilute solution of  $\text{KMnO}_4$  add a small piece of zinc and a few drops of  $\text{H}_2\text{SO}_4$ . Heat? Note results with equations for reactions.

**240.** Try the action of a speck of  $\text{MnO}_2$  on a borax or sodium metaphosphate bead heating first in the oxidizing blowpipe flame, cooling, examining color and then heating in the reducing flame.

**241.** Add a speck of  $\text{MnO}_2$  or any manganese compound to a mixture of dry  $\text{Na}_2\text{CO}_3$  and  $\text{NaNO}_3$  on platinum foil. Turn up the edges of the foil on three sides forming a box-like receptacle. Leave one of the narrow edges flat so that it may be held easily by the forceps. Heat to fusion. Dissolve in water and add dilute  $\text{H}_2\text{SO}_4$  a drop at a time. Note results and write equations for reactions.

**242.** Define oxidation; reduction. Classify such reactions on sheets 51 and 52 stating which compound is oxidized and which is reduced in each case.

**237, 238, 240 and 241** serve to identify Mn.





## 53 PREPARATION OF POTASSIUM PERMANGANATE\*

243. Place a mixture of 12 grams of KOH and 7 grams of  $\text{KClO}_3$  in a 2 in. iron crucible. Heat the mixture carefully until it is just melted. While waiting grind 12 grams of pyrolusite to as fine a powder as possible (the finer it is ground the more successful the preparation). Remove the flame from under the crucible and add the pyrolusite, a little at a time, stirring vigorously with a file all the while.† After all is added place a small flame below the crucible and keep stirring the charge. Gradually increase the strength of the flame, and stir continuously until the mass stiffens completely. Then cover the crucible and heat it five minutes longer at a dull red heat. When the mass has cooled, place crucible and all in 250 cc. of water in a 6 in. porcelain dish. After the solid has entirely disintegrated, remove the crucible and rinse it off with a little water from the wash bottle. Boil the solution in the dish and at the same time pass in  $\text{CO}_2$  generated from marble and HCl until the green color of the manganate has entirely changed to the violet red color of the permanganate. Test the color by touching a drop of the solution on a stirring rod to a piece of filter paper. If the spot is violet with no trace of green and only a fleck of brown manganese dioxide in the center, the change to permanganate is complete. Remove the flame, let the sludge settle in the dish for five minutes; then pour the solution through an asbestos filter, being careful to avoid stirring up the sludge until the very last, since the slimy precipitate of the manganese dioxide would so clog the filter as to nearly stop the flow. Lastly, with the aid of a jet of water from a wash bottle, transfer all the sludge to the filter and drain it free from liquid. Evaporate the solution in a clean dish to a volume of 75 cc. Let it settle a moment and filter through asbestos as before. Pour the filtrate into a 6 in. dish, and allow it to cool slowly in a place protected from the dust. When cold, collect the crystals of potassium permanganate on a perforated plate placed loosely in a filter funnel. Evaporate the mother liquor to 25 cc. filter it through asbestos, and obtain second crop of crystals. Discard the remaining liquid, since it cannot contain more than about 2 g. of  $\text{KMnO}_4$  and to evaporate further would cause KCl also to crystallize out. Weigh all the crystals, dissolve them in eight times their weight of water (to give a saturated solution at  $40^\circ$ ), filter the solution heated almost to boiling through asbestos, and let it cool slowly and crystallize in a small porcelain dish covered with a watch glass. Recover another crop of crystals in the same way from the mother liquor, after evaporating it to a volume of 60 cc. Allow the crystals to dry on a clean clock glass.

\* This method with slight modification, is taken from Blanchard's Synthetic Inorganic Chemistry.

† Since the charge in the crucible effervesces and spatters particles of melted salt, great care should be taken to keep the eyes at a safe distance. The hand holding the stirrer should be protected with a thick glove or with a towel, and with the other hand the crucible should be held firmly by means of long iron tongs.



## 54. IRON

**Ferrous Salts.** Prepare the solution by dissolving a few small wire nails in dilute HCl. Give equation for reaction.

**244.** To a little of the solution (diluted) add NaOH until a precipitate forms. Note results and write equation for the reaction. Try the solubility of the precipitate in dilute acids.

**245.** Try the action of  $(\text{NH}_4)_2\text{S}$ , noting results and giving equations for reactions. Try the solubility of the precipitate in dilute acids.

**246.** Try the action of  $\text{K}_4\text{Fe}(\text{CN})_6$  (potassium ferrocyanide), note results and write equation for reaction. Repeat, substituting  $\text{K}_3\text{Fe}(\text{CN})_6$  (potassium ferricyanide); KCNS (potassium thiocyanate). The second reagent serves as a test for the ferrous ion.

**247.** To remainder of  $\text{FeCl}_2$  solution add a little conc.  $\text{HNO}_3$  and boil until brown fumes cease coming off. Give equation for the reaction.

**248.** Dilute a little of the  $\text{FeCl}_3$  just formed and try the action of NaOH. Note result and write equation for reaction. Try the solubility of the precipitate in dilute acids. Also in an excess of NaOH (compare Al).

**249.** Try the action of  $(\text{NH}_4)_2\text{S}$  on dilute  $\text{FeCl}_3$ , noting results with equations for reactions. Try the solubility of the precipitate in dilute acids.

**250.** Repeat 246, making tests on dilute  $\text{FeCl}_3$ . The first and last reagents are tests for the ferric ion.

**251.** To dilute  $\text{FeCl}_3$ , containing a little free acid, add a few granules of zinc and warm until the color disappears. Write the equation for the reaction. How can you distinguish between ferrous and ferric salts?

**252.** Give the formulas and color of compounds formed by the reagents indicated in the following tabular outline, stating whether they are solutions or precipitates:

Action of	$\text{HNO}_3$	Zn	NaOH	$(\text{NH}_4)_2\text{S}$	$\text{K}_4\text{Fe}(\text{CN})_6$	$\text{K}_3\text{Fe}(\text{CN})_6$	KCNS
On ferrous chloride forms.....	.....	.....	.....	.....	.....	.....	.....
On ferric chloride forms.....	.....	.....	.....	.....	.....	.....	.....





## 55. NICKEL AND COBALT

**253.** Try the action of the following reagents on dilute solutions of nickel and cobalt salts, comparing results and giving equations for reactions. Also try the effect of an excess of the first three reagents:  $\text{NaOH}$ ;  $\text{NH}_4\text{OH}$ ;  $(\text{NH}_4)_2\text{S}$ ;  $\text{H}_2\text{S}$  water in acid solution of the salts; dimethylglyoxime in presence of ammonia;  $\text{NaNO}_2$  (sodium nitrite) in presence of a slight excess of  $\text{HC}_2\text{H}_3\text{O}_2$  (acetic acid).

**254.** Try the effect of a particle of nickel and cobalt compound on the borax or phosphate bead in the oxidizing and the reducing blowpipe flame.

How would you test for cobalt and nickel on the basis of the above reactions? How separate them?





## 1. REFERENCE BOOKS IN INORGANIC CHEMISTRY

The following may be obtained in the Technology Departments of first class libraries.

- ASHLEY—*Chemical Calculations*.  
 BLAKE—*General Chemistry*.  
 BYERS—*Inorganic Chemistry*.  
 CADY—*General Chemistry*.  
 CADY—*Inorganic Chemistry*.  
 HALE—*Calculations in General Chemistry*.  
 HILDEBRAND—*Principles of Chemistry*.  
 HOLLEMAN—*Text-book of Inorganic Chemistry*.  
 KAHLENBERG—*Outlines of Chemistry*.  
 MCPHERSON AND HENDERSON—*Chemistry for Colleges*.  
 MELLOR—*Modern Inorganic Chemistry*.  
 NEWELL—*College Chemistry*.  
 NEWTH—*Inorganic Chemistry*.  
 NOYES—*Text-book of Chemistry*.  
 NOYES—*Text-book of College Chemistry*.  
 REMSEN—*College Chemistry*.  
 SMITH—*General Chemistry for Colleges*.  
 SMITH—*Inorganic Chemistry*.  
 STODDARD—*Introduction to General Chemistry*.  
 THORPE AND TATE—*Chemical Problems*.  
 WELLS—*Chemical Arithmetic*.

For more elementary material see

- BLANCHARD AND WADE—*Inorganic Chemistry*.  
 BRADBURY—*Inductive Chemistry*.  
 BROWNLEE—*First Principles of Chemistry*.  
 MCPHERSON AND HENDERSON—*Elementary Study of Chemistry*.  
 NEWELL—*Descriptive Chemistry*.  
 SMITH—*Elementary Chemistry*.

For more advanced material see

- FRIEND—*Text-books of Inorganic Chemistry*.  
 GMEHLIN-KRAUT—*Handbuch der Anorganischen Chemie*.  
 MENDELEJEFF—*The Principles of Chemistry*.  
 MOLINARI—*General and Industrial Chemistry*.  
 OSTWALD—*Principles of Chemistry*.  
 ROSCOE AND SCHORLEMMER—*Treatise on Chemistry*.  
 THORPE—*Dictionary of Applied Chemistry*.



## 2. MATTER, ENERGY, CHANGE, ELEMENT, COMPOUND

- \*1. Define specific properties and give examples.
- \*2. Define substance; mixture; body; components. Give examples.
- \*3. Explain rusting and describe an experiment which shows the cause. How is the weight of the substance affected?
- \*4. State the Law of Component Substances; the Law of Chemical Change.
- \*5. Illustrate the first variety of chemical change (combination). Define compound; constituent. Give examples.
- \*6. Define specific gravity; tenacity; melting point.
- \*7. Define matter. State the Law of Conservation of Matter. Give examples illustrating your definition.
- \*8. Define energy and state the Law of Conservation of Energy. Give examples.
- \*9. Define *chemistry* and discuss its relation to other sciences briefly. Is there a sharp boundary line between sciences?
- \*10. What is meant by the "physical" properties of matter? Give examples.
- \*11. What is a chemical change? Give examples.
- \*12. What is a physical change? Give examples.
- \*13. State the kind of change which takes place in the following: Burning of wood; freezing of water; souring of milk; melting of gold.
- \*14. What is an element? Give examples.
- \*15. What is a compound? Give examples.
- \*16. How can you distinguish between a mixture and a compound? Illustrate fully by describing experiments conducted with iron and sulphur.
- \*17. Various forms of energy are liberated or taken up in chemical changes. Name as many as possible.
- \*18. Define reagent. What is chemical action. Give examples.
- \*19. Are all elements equally abundant in the Earth's crust? Name the first five in the order of their abundance.
- \*20. Give the Metric weights and measures and their abbreviations.
- \*21. On what is the gram weight based? What is a cubic centimeter?
- \*22. Compare the Centigrade and Fahrenheit thermometric scales.
- \*23. How may a pure substance be prepared?
- \*24. Discuss, briefly, directions to be observed in the manipulation of glass tubing for preparation of a wash bottle.
- \*25. Name three factors which govern the rate of a chemical reaction. (Temperature, pressure, concentration).
- \*26. Illustrate the second variety of chemical change (decomposition).
- \*27. Define hypothesis; theory; law. Illustrate by examples.





### 3. OXYGEN

1. Give the history of oxygen.
- \*2. Discuss occurrence of oxygen in nature both free and in combination.
- \*3. Give three laboratory methods for the preparation of oxygen. State what happens and prepare a neat sketch of the apparatus used for the potassium chlorate method.
- \*4. Describe the following commercial methods thoroughly: Brinn; electrolytic; liquid air.
- \*5. What is "oxone" and how may it be utilized for the preparation of oxygen?
- \*6. Give the chemical and physical properties of oxygen together with reactions which take place. Mention substances indifferent to oxygen.
- \*7. Discuss oxygen in respect to its relation to life.
- \*8. Give the principal uses of oxygen.
- \*9. Name some compounds of oxygen and tell how they are formed.
- \*10. What is a catalytic or contact agent? Give example.
- \*11. Why is it necessary to remove the delivery tube from the water before removing the flame from an oxygen generator?
- \*12. How would you test for oxygen?
- \*13. Define decomposition and combination, and show how these two kinds of chemical change are illustrated in the study of oxygen.
- \*14. Define oxidation; burning; oxidizing agent; combustion; spontaneous combustion; kindling temperature; decay.
- \*15. Potassium chlorate contains 39 per cent of oxygen. How many grams of oxygen can be prepared from 630 grams of potassium chlorate?
- \*16. How many grams of oxygen can be obtained from 250 grams of potassium chlorate containing 10 per cent of impurity?
17. What is the weight of 10 liters of oxygen? 500 cc.?
18. A room is  $25 \times 25 \times 12$  meters in size. What weight of oxygen does it contain if the air is of normal composition?
- \*19. How is oxygen collected? Prepare a sketch illustrating the process. How is it put up for commercial use?
- \*20. How do you account for the difference in rate of combustion of substances in oxygen and air?
- \*21. Define calorie; heat of combustion. How many calories of heat are given off in the burning of 1 gram of charcoal? Sulphur? Iron?
- \*22. Describe an experiment which shows the combining proportion of oxygen with another element.
- \*23. Define activity; stability. Illustrate.





4. ATOMS, MOLECULES, SYMBOLS, FORMULAS

- \*1. What is meant by "the composition of substances?" Give examples.
- \*2. State the Law of Combining Weights and give examples. Does this apply to substances or mixtures?
- \*3. Define atom; atomic weight; molecule; molecular weight. Give examples.
- \*4. State Dalton's Atomic Theory.
- \*5. What is a chemical symbol? A formula? An equation? Write several of each.
- \*6. How can a formula be derived from an analysis? Give examples.
- \*7. State the Law of Multiple Proportions.
- \*8. How can you calculate the percentage composition of a compound substance, knowing its formula? Calculate the percentage composition of all compounds used in the preparation of oxygen. (See table of atomic weights on inside of rear cover of your text-book.)
- \*9. Calculate the amount of iron and sulphur necessary for the preparation of 87.9 grams FeS. What type of chemical change is represented?
- \*10. Calculate the weight of oxygen obtainable from 10 grams each of  $\text{KClO}_3$ ;  $\text{HgO}$ ;  $\text{Na}_2\text{O}_2$ ;  $\text{H}_2\text{O}$ .



## 5. HYDROGEN

- \*1. Discuss the history of hydrogen.
- \*2. Discuss the occurrence of hydrogen in nature both free and in combination. Compare these data with those observed for oxygen.
- \*3. How has it been possible to prove the presence of hydrogen in the atmosphere of the Sun?
- \*4. Give as many laboratory and commercial methods as possible for the preparation of hydrogen. Write equations for reactions. Which laboratory and which commercial method do you consider the most important?
- \*5. Compare methods for the preparation of hydrogen and oxygen and mention the most apparent differences.
- \*6. Give the physical and chemical properties of hydrogen. Write equations for reactions.
- \*7. Mention the most striking differences in the properties of hydrogen and oxygen.
- \*8. What can you say of the rate of diffusion of hydrogen as compared with oxygen? Give formula generally accepted for the rate of diffusion of gases.
- \*9. Mention the principal uses of hydrogen, including war uses.
- \*10. What is a reducing agent? An oxidizing agent? Describe an experiment to illustrate each.
- 11. Prepare a sketch of the Kipp generator and show how it may be used for the preparation of hydrogen.
- \*12. Describe a simple test by which you can distinguish between hydrogen and oxygen.
- \*13. Distinguish between a combustible substance and one which supports combustion.
- \*14. Calculate the volume which 5 grams of hydrogen will occupy under standard conditions of temperature and pressure.
- \*15. The density of chlorine is about thirty-six times that of hydrogen. Compare the rate of diffusion of the gases.
- 16. A certain gas passes through a porous partition 2.5 times slower than hydrogen. What is its density?
- \*17. If 98 grams of sulphuric acid yield 2 grams of hydrogen, how many liters of hydrogen can be obtained from 137 grams of sulphuric acid?
- \*18. What is a reversible reaction? Use iron and water as an example.
- 19. What is hydrone? Mention advantages to be derived from its use. How does the cost of this method compare with that of zinc and sulphuric acid or the electrolytic method?



- \*20.** What is meant by the hydrogen equivalent of a metal? Give example.
- 21.** Give several methods for drying gases and compare their drying values.
- 22.** Define acid; electrolyte; radical. Give examples of each.
- 23.** Prepare a sketch of the voltameter used for the electrolysis of water and state the function of each part.
- \*24.** What is meant by "the activity of an element"? Explain the "order of activity of metals."
- 25.** Define displacement; double decomposition. Give examples with equations for reactions.
- \*26.** What influence do temperature and pressure have on the rate of combination of oxygen and hydrogen? Mention a catalytic agent which changes the rate.

## 6. VALENCE AND CALCULATIONS

\*1. Define valence.

\*2. Which element serves as the unit of valence? How may the valence of other elements be derived from this? Give examples of mono, bi and trivalent elements.

\*3. How may valence be indicated in ordinary formulas? In structural formulas? Write both for  $\text{Fe}_2\text{O}_3$ ,  $\text{FeCl}_3$ ,  $\text{NaCl}$ ,  $\text{Na}_2\text{O}_2$ ,  $\text{CaCl}_2$ ,  $\text{HCl}$ .

\*4. Describe an experiment which shows the respective valences of Na, Ca and Al.

5. Discuss the valence of radicals. Write the formulas for sodium sulphate, sodium hydroxide, calcium sulphate, aluminium sulphate, calcium hydroxide, aluminium hydroxide. What is the valence of the sulphate radical? The hydroxyl radical? The chlorate radical? Write the formula for barium chlorate.

\*6. How should the total valence of two parts of a compound be related? Of two sides of an equation? Write the equation for the action of water on sodium peroxide and sulphuric acid on zinc signifying the valence of each element or radical.

\*7. Show by examples how it is possible to learn the valence of a new element from its compounds with elements whose valence you already know.

8. Does the valence of an element ever vary? If so, give examples.

9. Mention a case of exceptional valence and show how the difficulty is overcome by changing the formula to a combination of two formulas.

10. Discuss "nomenclature of compounds" and give examples including variable valence.

\*11. What is meant by "equivalent weight"? Illustrate graphically for Na, Mg, Al. Give a general formula for equivalent weight. Change it to a valence formula.

\*12. How can you calculate the weight of a substance which will form if the weight of another substance in the equation is given? (The atomic or molecular weight of the substance given is to the atomic or molecular weight of the substance required as the actual weight of the substance given is to  $x$ .)

*Example.* Calculate the weight of oxygen obtainable by the action of water on 10 grams  $\text{Na}_2\text{O}_2$ .



$$\frac{2 \times 78}{156} + \frac{2 \times 18.016}{36.032} = \frac{4 \times 40.008}{160.032} + \frac{2 \times 16}{32}$$

$$156 : 32 = 10 \text{ g.} : x.$$

$$x = \frac{32 \times 10 \text{ g.}}{156} = 2.05 \text{ g.}$$

\*13. How can you calculate the percentage composition of a compound substance? Calculate these values for  $\text{KClO}_3$ ,  $\text{Na}_2\text{O}_2$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{NaCl}$ ,  $\text{NaOH}$ .

\*14. Calculate the formula of the substance whose composition follows: Platinum 57.92 per cent, chlorine 42.08 per cent, using the atomic weights;  $\text{Pt} = 195.2$  and  $\text{Cl} = 35.46$ .

\*15. (a) Calculate the weight of hydrogen obtainable by the action of  $\text{H}_2\text{SO}_4$  on 10 g. Zn. (b) How much  $\text{ZnSO}_4$  will form? (c) How much  $\text{H}_2\text{SO}_4$ ?

\*16. How much  $\text{KCl}$  forms when 10 g.  $\text{KClO}_3$  is heated in the preparation of oxygen?





## 7. PROPERTIES OF GASES, LAWS, CALCULATIONS, ETC.

\*1. Describe the Bunsen barometer.

\*2. How may the pressure of a gas be measured? Should a correction be made for the temperature of the liquid over which a gas is collected? Why? How does this compare for mercury and water?

\*3. How does the volume of a gas vary with the pressure, the temperature remaining constant? State the law (Boyle, 1660) which covers pressure effects.

\*4. A gas occupies a volume of 100 cc. under a pressure of 750 mm. What would its volume be under 760 mm. pressure? Under 790 mm.? Under 710 mm.?

\*5. A gas occupies a volume of 100 cc. under a pressure of 770 mm. What would its volume be under 760 mm. pressure? Under 790 mm.? Under 730 mm.?

\*6. How does the volume of a gas vary with temperature, the pressure remaining constant? State the law (Charles, 1787; sometimes called the law of Gay-Lussac and Dalton) which covers temperature effects. Show graphically how the absolute zero is calculated. How absolute temperatures compare with Centigrade temperatures.

\*7. A gas occupies 500 cc. at 20° C. What will its volume be at 0° C.? At 10° below zero Centigrade? At 60°?

\*8. A gas occupies a volume of 100 cc. at 20° below zero Centigrade. Calculate its volume at 0° C.; at 20° C.; 70° below zero Centigrade.

\*9. The gas laws apply simultaneously so it is only necessary to multiply a given volume by the fractions for pressure and temperature corrections. *Example.* Given 100 cc. of gas at 20° C. and under 740 mm. pressure to calculate (a) its volume at 0° C. and under 760 mm. pressure; (b) at 30° and under 780 mm.; (c) at 20° below zero Centigrade under 710 mm.

$$(a) \quad 100 \text{ cc.} \times \frac{273}{293} \times \frac{740}{760} = \text{desired volume.}$$

$$(b) \quad 100 \text{ cc.} \times \frac{303}{293} \times \frac{740}{780} = \text{desired volume.}$$

$$(c) \quad 100 \text{ cc.} \times \frac{253}{293} \times \frac{740}{710} = \text{desired volume.}$$

\*10. State Dalton's Law of Partial Pressures (1807) which applies to mixed gases.

11. Define aqueous tension; vapor pressure. Cite an example for water and show how a correction should be made for same.

\*12. What is meant by the "density of a gas?" Compare a number of gases with hydrogen and with air, and calculate their densities on the basis of each.

13. How may the density of a gas be determined experimentally?

**\*14.** Discuss the molecular structure of gases. How do you account for the ability to compress a gas to a much smaller volume? What causes a gas to fill the entire space in a containing vessel?

**\*15.** In what respect do all gas molecules resemble each other? Why do the molecules not settle to the bottom of the containing vessel?

**\*16.** How do the rates of diffusion of various gases compare?

**\*17.** How do you account for an increase in pressure when the volume of a gas is reduced? The reduction of pressure with increased volume? Beginning with 1 liter of gas calculate and account for the volume when the pressure is doubled; when the pressure is reduced by one-half.

**\*18.** How is the velocity of a gas molecule affected by temperature? What result does this have on the volume occupied by a gas?

**\*19.** State Avogadro's Law (1811) and mention facts regarding gases which tend to confirm the law.

**\*20.** What happens when gases cohere through the effect of pressure and low temperatures? Does this seem consistent with the behavior of gas molecules through change of volume and temperature?

**\*21.** Define critical temperature; critical pressure.

**\*22.** When a gas through compression and cooling occupies a smaller volume than that calculated according to Boyle's and Charles' laws (i.e., possesses a greater density than it should for that temperature and pressure) how do you account for the discrepancy? How do you account for its occupying a greater volume than the calculated one for certain pressures at times?

**\*23.** State completely the "Kinetic Molecular Theory of Gases."

**\*24.** Discuss "Molecular Relations in Liquids."

**\*25.** Discuss "Molecular Relations in Solids."

**\*26.** What is crystallization?

**\*27.** Mention the six crystal systems and draw the simplest type of each system showing its axes.

**\*28.** Does the vapor pressure of a solid or liquid equal the pressure of an equal weight of gas confined to the same space?



## 8. WATER

\*1. Define calorie; specific heat. How do specific heats of other substances compare with that of water? How many calories of heat are liberated when the following reaction takes place:  $2\text{H}_2 + \text{O}_2 = 2\text{H}_2\text{O}$ ?

\*2. Define heat of fusion; heat of vaporization. What are these values for water?

3. What is a "transition point?" Give examples.

4. Define solution pressure; vapor tension; aqueous tension; humidity.

\*5. Define equilibrium and discuss fully. How is equilibrium between liquid and vapor affected by temperature? Between solid and vapor as in the case of iodine or ammonium chloride?

\*6. Define solvent; solute. How is equilibrium between solvent and solute generally affected by temperature?

\*7. What is a saturated solution? A supersaturated solution? Give examples.

\*8. Mention classes of impurities contained in natural waters and describe a method for the removal of each class.

\*9. How may bacteria contained in water be destroyed? Mention three methods.

10. What is meant by "hardness of water?"

\*11. Give the physical and chemical properties of water.

\*12. Define association and dissociation and illustrate in the case of water. Is water a stable or an unstable compound?

\*13. Define base; acid; basic oxide; acidic oxide; acid anhydride; metallic element; non-metallic element. Give examples of each.

\*14. What are hydrates? Give examples.

\*15. Define water of crystallization and give several examples.

\*16. Define efflorescence and give examples.

\*17. How can you show by experiment and calculations that you have  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  and not  $\text{CuSO}_4 \cdot \text{H}_2\text{O}$ ?  $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$  and not  $\text{BaCl}_2 \cdot \text{H}_2\text{O}$ ?  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$  and not  $\text{ZnSO}_4 \cdot \text{H}_2\text{O}$ ?

\*18. Prove the composition of water by reduction of  $\text{CuO}$ ; by electrolysis of water; by synthesis through explosion of the constituent elements. Prepare a sketch of the apparatus used in each case.

\*19. State Gay-Lussac's Law of Volumes and illustrate by results obtained in formation of  $\text{H}_2\text{O}$ .

20. If you have 100 liters of water vapor at  $300^\circ \text{C}$ . and under a pressure of 730 mm. calculate the volume of hydrogen and oxygen (standard condition) required for its formation. Also calculate the weight of each reacting substance and of water formed.



\*21. Calculate the volumes of oxygen and hydrogen which will result from the electrolysis of 10 g.  $\text{H}_2\text{O}$  at  $20^\circ \text{C}$ . under 740 mm. pressure.

22. Describe a number of methods for the preparation of water. Give reactions which take place.

\*23. Mention various gases found dissolved in natural waters and state how they are introduced. Which of these are to be expected and which may be considered impurities?

24. Describe sand filtration. Prepare an ideal sketch of a sand and gravel filter plant.

25. Compare spring water, river and sea water as to composition and fitness for domestic use. How does rain water compare with these?

26. Why has water been called the universal solvent?

\*27. Discuss fully occurrence of water in nature.

28. State amount of water found in a number of common food products.

\*29. How much water would be required to convert 10 grams of copper to copper oxide? Calculate the volume of hydrogen (standard conditions) which would result.

30. How can you prove the presence of water in minerals? Prepare a sketch of the apparatus used.

\*31. Name three methods for removing moisture from gases.

32. How does the territory through or over which water flows determine its composition? Define erosion.

33. Discuss various types of household filters as to efficiency and care necessary in their use.

34. Is temperature a factor in the purification of water? How does a very low temperature affect it? A high temperature?

35. Account for the breaking of glass vessels containing milk in cold weather. What is meant by the maximum density of water?

36. What do you understand by the water cycle?

37. Why is it important to know the source of supply of a water? Is a clear sparkling spring water necessarily safe?

\*38. What effect does pressure have on boiling-point of water? On the freezing-point?

39. How does the addition of soluble substance affect the freezing-point of water? Give a common example. What is the lowest point obtainable by any salt called? What would happen if more salt or water were added?

40. Define phase. Illustrate graphically for the three forms of water using the ordinate for vapor pressures and the abscissa for temperatures.

\*41. Describe the method for the determination of water of crystallization in hydrated barium chloride.

42. Prepare a neat sketch of apparatus used in the distillation of water.

\*43. Calculate the volume of hydrogen and oxygen obtainable from 25 g. water measuring the gases at  $23^\circ \text{C}$ . under a pressure of 740 mm.

## 9. ATOMIC AND MOLECULAR WEIGHTS, GAY-LUSSAC'S LAW, ETC.

- \*1. State Gay-Lussac's Law of Combining Volumes. Give an example showing both weight and volume relations.
- \*2. Define gram-molecular volume. Mention temperature and pressure conditions under which this standard is taken.
- \*3. Mention the weights of oxygen, hydrogen and water contained in a gram-molecular volume.
- \*4. How can the gram-molecular volume value be used for determining molecular weights of gases? Give examples. What is a gram-molecular weight? A molar weight? A molar volume? A mole? A formula weight?
- \*5. State Avogadro's law and show graphically how you interpret same.
6. What is the Millikan value for the number of molecules in a mole of substance?
- \*7. How is the atomic weight of an element determined from the composition of a number of its compounds? In elementary gases, how does it usually compare with the molar or molecular weight? See oxygen, hydrogen, nitrogen, chlorine.
- \*8. Why was 22.4 liters chosen as the desirable volume?
9. Mention some advantages derived from the use of atomic weights.
- \*10. Give DuLong and Petit's method for determining atomic weights.
11. Show that both composition and the weight of a gram-molecular volume are necessary for the derivation of formulas of some compounds.
- \*12. Show graphically why the molecules of oxygen, hydrogen, chlorine, nitrogen, etc., must contain at least two atoms.
- \*13. Write molecular equations for the following reactions: Sodium peroxide+water; iron (red hot)+steam; zinc+sulphuric acid; aluminium+hydrochloric acid; explosion of hydrogen and oxygen; action of sodium on water; mercuric oxide+heat.
- \*14. Do the atoms of metallic elements combine with each other in the vapor state to form molecules as in the case of non-metals?
- \*15. 6.2 liters of hydrogen weighed 0.557194 gram under standard conditions. Calculate the molecular weight of hydrogen.
- \*16. 11.1 liters of oxygen weighed 15.8619 grams under standard conditions. Calculate the molecular weight of oxygen.
- \*17. How can you figure the weight of a liter of a gas knowing its molecular weight? Knowing its atomic weight? Work a problem illustrating each.
18. Using the gram molecular weight of several elementary gases and knowing that 22.4 liters of air weigh 29 grams, calculate the density of these gases referred to air.





## 10. SOLUTION

\*1. Define solution; solvent; solute. Give examples.

\*2. What is a colloidal suspension? If not visible by ordinary means how may it be rendered visible?

\*3. What are the three states of matter? Give examples of each. How are they affected by temperature and pressure changes?

\*4. Are all substances equally soluble in water? Give examples to illustrate your answer.

\*5. How is solubility usually affected by changes of temperature and pressure? Answer for both solids and gases in liquids. What is meant by the term concentration? Dilute?

\*6. How may a dilute solution of a solid in a liquid be concentrated? Of a gas in a liquid?

\*7. Define molar solution; normal solution. Give examples.

\*8. Define heat of solution and give an example.

\*9. Discuss "diffusion in liquids." Mention a theory applied to gases, which seems to account for this phenomenon in liquids. To what in a gas volume might the solvent in a solution be compared, when diffusion takes place?

\*10. What is osmotic pressure (or suction)? Solution pressure? Illustrate by examples. Describe an apparatus in which osmosis experiments may be performed. The following phenomena are observed when a semi-permeable membrane separates a pure solvent from a solution or a dilute solution from a stronger one:

(a) "The solvent passes through the membrane into the solution." Why?

(b) "The solvent passes through the membrane from the more dilute to the more concentrated solution." Why?

(c) "The entrance of the solvent can be prevented by applying pressure to the stronger solution." Why?

(d) "The value of the pressure (or suction) increases in proportion to the temperature." Why?

(e) "The value of the pressure (or suction) is proportional to the concentration of the solution." Why?

(f) "Equal numbers of molecules of different solutes of the same type dissolved in equal volumes of solvents create (almost) equal pressures." Why?

(g) "The osmotic pressure (or suction) exercised by a gram-molecular weight of non-ionized solute in 22.4 liters of solvent is almost identical with the pressure exerted by a gram-molecule of gas occupying 22.4 liters." Why?

\*11. Define equilibrium. Give graphic examples for equilibrium between a liquid and its vapor in an isolated system. Also for equilibrium between a solid substance and its solution.

\*12. Discuss the solubility of mixed gases in a liquid (Dalton's Law).

**13.** Discuss the solubility of a solid or gas in two immiscible liquids. What is the process of removing a substance from solution in a liquid by another liquid, in which it is more soluble, called?

**\*14.** How does the equilibrium in saturated solutions of solids vary with temperature? On this basis, interpret the solubility curves for various salts.

**\*15.** Define supersaturated solution and give an example; also define saturated solution. How does the latter vary with the temperature?

**\*16.** How does a substance in solution affect the freezing-point and boiling-point of the solution?

**\*17.** Does the depression of the freezing-point and the raising of the boiling-point by substances in solution enable us to determine their molecular weights? How much will a gram-molecule of alcohol or sugar lower the freezing-point if dissolved in a liter of water?

**18.** Define deliquescence in terms of the vapor tension of the deliquescent substance. Describe two experiments which show phenomena resulting from differences in vapor tension.

**\*19.** What is the "density" or specific gravity of a solution?

**20.** When one substance dissolves in another is the total volume equal to the sum of the original volumes? Give examples to illustrate your statement.

**21.** Is solution a physical or a chemical change? Illustrate.



## 11. HYDROGEN CHLORIDE

\*1. Describe the most important method for the preparation of HCl, giving equations for reactions at room temperature and on application of heat. How may the gas be prepared directly from the elements?

\*2. What happens when you add a concentrated aqueous solution of HCl to a saturated solution of  $\text{NaHSO}_4$ ? How do you account for the difference between this reaction and the one obtained in the preparation of HCl?

\*3. Define chemical equilibrium. Do temperature and concentration influence same? Give examples for  $\text{NaCl}$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{NaHSO}_4$  and HCl.

\*4. Give the physical properties of HCl. Describe an experiment which illustrates the great solubility of HCl.

\*5. Give the chemical properties of HCl with equations for reactions. Also give the chemical properties of the aqueous solution.

\*6. How may chlorides be prepared? Give equations for reactions.

\*7. Describe fully one method for showing the composition of HCl gas.

\*8. What are the principal uses of HCl?

\*9. Define precipitate and mention some of the forms in which substances are precipitated.

\*10. Define double decomposition and give an equation to illustrate same. Also mention three other varieties of chemical change and give an equation to illustrate each."

\*11. Define electrolyte; non-electrolyte. Give several examples of each. Describe an experiment which enables us to distinguish one from the other.

\*12. Define ion; anion; cation; anode; cathode. Write ionic formulas for the following in aqueous solution;  $\text{NaOH}$ ,  $\text{NaCl}$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{Na}_2\text{SO}_4$ ,  $\text{CuSO}_4$ ,  $\text{BaCl}_2$ , HCl.

**Note.** Hereafter write ionic formulas for all substances which ionize readily in water, providing they are in solution in the experiment.

\*13. Define electrolysis and cite an example.

\*14. Define acid; base; salt; acid salt; basic salt and give examples.

\*15. State two methods by which the volume of a given weight of gas may be calculated.

\*16. Show graphically how Gay-Lussac's Law applies in the preparation of HCl from its constituents. What evidence have we that the molecule contains at least two atoms, assuming that the atomic theory and Avogadro's Hypothesis hold good?

\*17. Illustrate Gay-Lussac's Law graphically by a number of other gas reactions, showing how the initial and resulting volumes are related numerically.



**\*18.** Define gram-molecular volume; gram-molecule; molar weight; formular weight. Give examples.

**\*19.** What is meant by the relative densities of gases? Mention two standards used.

**\*20.** What is the weight of a gram-molecular volume of hydrogen chloride? Oxygen? Hydrogen?

**\*21.** How many gram-molecular volumes of hydrogen chloride (measured under standard conditions) will result, theoretically, if sodium chloride is treated with 98.076 g. sulphuric acid in the cold? If heat is applied? What will the gas measure at  $23^{\circ}$  under 730 mm. pressure?

**\*22.** Given 24.64 liters of HCl at  $27.3^{\circ}$  C., under 760 mm. pressure calculate the quantity of sodium chloride needed for its production. Na=23, Cl=35.46, H=1.008.

**\*23.** If sodium removes the chlorine from 22.4 l. HCl confined over mercury what volume of hydrogen (standard conditions) will remain? What weight of sodium chloride will result?

**\*24** How many gram-molecular volumes of HCl are necessary for the neutralization of 40.008 g. of NaOH? For the conversion of 81.37 g. ZnO (zinc oxide) to  $\text{ZnCl}_2$  (zinc chloride)? Zn=65.37, Na=23, O=16, H=1.008, Cl=35.46.

## 12. CHLORINE

1. Discuss the history of chlorine.
- \*2. Discuss the occurrence of chlorine compounds in nature.
- \*3 Give the most important laboratory method for the preparation of chlorine, with equation for reaction. Show how a change in valence of one of the reacting substances is responsible for the process.
4. Describe Deacon's process for the manufacture of chlorine. Mention impurities which accompany the chlorine. Write equation for reaction. Note that temperature and the use of a contact agent are important factors.
- \*5. What is a reversible reaction? Mention two important factors which determine the direction which a reaction will take. Write equations for the preparation of HCl from NaCl and  $\text{H}_2\text{SO}_4$ , stating conditions under which the reaction proceeds in one direction or the other. Also consider the reaction between HCl,  $\text{O}_2$ ,  $\text{H}_2\text{O}$  and  $\text{Cl}_2$ .
- \*6. Define equilibrium and mention factors which tend to shift the equilibrium point in a reaction.
- \*7. Describe the electrolytic method for the preparation of chlorine from HCl. Why do we not obtain a volume of chlorine equal to that of the hydrogen at the beginning of the experiment? What would happen if you used a solution of NaCl instead of HCl? If you employed fused NaCl? Give equations for reactions using ionic formulas.
- \*8. Write the equation for the preparation of chlorine from HCl through the action of  $\text{KMnO}_4$  or  $\text{K}_2\text{Cr}_2\text{O}_7$ .
- \*9. Give the physical properties of chlorine. What is the weight of a gram-molecular volume of the element?
- \*10. Give the chemical properties of chlorine including reactions with hydrogen, antimony, copper, iron, sodium, turpentine ( $\text{C}_{10}\text{H}_{16}$ ), phosphorus, etc. Mention elements displaced by chlorine and write equations for reactions.
11. How does chlorine act on organic compounds like methane? Show structurally four compounds which might result in the case of methane and give equations for reactions.
12. What is chlorine hydrate and how may the solid be prepared?
- \*13. Describe an experiment which proves that  $\text{H}_2 + \text{Cl}_2 = 2\text{HCl}$ , (a) by combination of the elements, (b) by decomposing HCl. State Avogadro's hypothesis; Gay-Lussac's Law.
- \*14. How would you test for chlorine? For the chlorine ion in chlorides? Write equations for reactions.
- \*15. Prepare a comparative outline showing the physical and chemical properties of  $\text{H}_2$ ,  $\text{O}_2$ ,  $\text{Cl}_2$ .
- \*16. Name the principal uses of chlorine.

\*17. Prove that moisture is necessary for bleaching with chlorine. Prepare a sketch of the apparatus used.

\*18. Calculate the weight of sodium chloride necessary for the preparation of a gram-molecular volume of chlorine.

19. The heat of combustion of  $\text{H}_2 + \text{O} = \text{H}_2\text{O}$  vapor is 58,000 calories; for  $\text{H}_2 + \text{Cl}_2 = 2\text{HCl}$  it is 44,000 calories. What would you expect if chlorine acted on  $\text{H}_2\text{O}$  with the formation of  $\text{HCl}$  and  $\text{O}_2$ , evolution of heat or a necessity for applying heat?

\*20. How many liters of chlorine may be prepared theoretically by the action of  $\text{HCl}$  on 86.93 g. of  $\text{MnO}_2$  (manganese dioxide)?  $\text{Mn} = 54.93$ ,  $\text{Cl} = 35.46$ .

\*21. How much  $\text{KMnO}_4$  is required for the preparation of 112 liters of chlorine?



## 13. ENERGY AND CHEMICAL CHANGE

\*1. Mention a number of reactions where heat is evolved during a chemical change. A number where heat is consumed. Write equations for reactions.

\*2. Mention a number of chemical changes where light is evolved. Also a number of changes that are brought about through the influence of light.

\*3. Mention several instances where electricity causes a chemical change to take place. Also a case where a chemical change develops electricity. Prepare neat sketches of apparatus used.

\*4. Can mechanical energy effect a chemical change? Does a chemical change ever develop mechanical energy? Give an example for each case.

\*5. Define kinetic energy; potential energy. Give an example of each.

\*6. Can one form of energy be converted into another? Give examples. Answer for heat, light, electricity, mechanical energy; also for kinetic and potential energy.

\*7. After considering the above how would you interpret a chemical formula in addition to the weight, volume and valence values already attributed to it?

\*8. If much energy were used in preparing a substance what would you expect when the reaction is reversed? On this basis would you suppose that much or little energy was employed in preparing  $O_2$ , Fe,  $Cl_2$ , Na, Mg?

9. May the chemical activity of a reacting substance be measured by the speed of the reaction? Give examples.

\*10. Define exothermal change; endothermal change. Give examples. To which type does the formation of water from its constituents belong? The formation of the elements from water?

11. Describe a piece of apparatus used for measuring thermal changes.

\*12. Define calorie. Write the thermochemical equation for the formation of water from its constituents.

\*13. Define heat of solution and give an example.

14. Define heat of ionization and give an example.

\*15.  $2H_2 + O_2 = 2H_2O$  (steam at  $100^\circ$ )  $+ 2 \times 57,600$  cal.

$2H_2 + O_2 = 2H_2O$  (water at  $100^\circ$ )  $+ 2 \times 68,400$  cal.

How much heat is necessary to convert 10 g. water weighed at the temperature of its maximum density into steam?



## 14. CHEMICAL EQUILIBRIUM

- \*1. Define reversible reaction and give several examples. How is reversibility usually indicated in an equation? Give an example. How is this expressed when the reaction proceeds farther in one direction than in the other. Give an example.
- \*2. Mention a number of reactions which proceed to completion.
- 3. Explain variations in the speed of a reaction on the basis of colliding molecules.
- \*4. Define chemical equilibrium; displacement of equilibrium.
- \*5. Discuss the effect of concentration on equilibrium. Give examples.
- \*6. State the laws of molecular concentration.
- \*7. Define equilibrium constant and given an example; ion-product constant.
- \*8. How does homogeneity affect the speed of a reaction? Heterogeneity? Give examples.
- \*9. How does temperature affect equilibrium? Illustrate by an isolated system containing HCl, O<sub>2</sub>, Cl<sub>2</sub>, and H<sub>2</sub>O (vapor). What happens when CaCO<sub>3</sub> is introduced into the tube?
- \*10. How is reversibility usually avoided in the laboratory and in industrial processes?
- \*11. How does concentration affect the speed of a reaction? Mention effect of temperature. Give examples.
- \*12. State Van't Hoff's Law and give examples to illustrate same. How does it apply to chemical reactions? To physical processes?
- \*13. State LeChatalier's Law. How is Van't Hoff's Law related to this?





## 15. BROMINE, IODINE, FLUORINE

- \*1. Discuss the occurrence of bromine compounds in nature.
- \*2. Give two laboratory methods for the preparation of bromine with equations for reactions.
- 3. Give a commercial method for the preparation of bromine.
- \*4. Show by partial equations how bromine is prepared from  $\text{KBr}$ ,  $\text{MnO}_2$  and  $\text{H}_2\text{SO}_4$ .
- \*5. Give the physical properties of bromine.
- \*6. Give the chemical properties of bromine with equations for reactions.
- \*7. Describe the most important method for the preparation of  $\text{HBr}$  preparing a neat sketch of the apparatus used and writing equations for reactions.
- \*8. Define hydrolysis and give an example.
- \*9. Compare the properties of  $\text{HBr}$  with those of  $\text{HCl}$ .
- \*10. Mention important uses of bromine and its compounds.
- \*11. Discuss the occurrence of iodine compounds in nature.
- \*12. Give two important methods for the preparation of iodine, writing equations for reactions.
- \*13. Give the physical properties of iodine.
- \*14. Give the chemical properties of iodine with equations for reactions.
- \*15. How may  $\text{HI}$  be prepared? Compare its properties with those of  $\text{HBr}$  and  $\text{HCl}$ .
- 16. Describe a lecture experiment which shows how  $\text{H}_2$  and  $\text{Br}_2$  may be united directly.
- \*17. Given two tubes, one containing  $2\text{HI}$  and the other  $\text{H}_2 + \text{I}_2$ . Both are heated to  $500^\circ$ . How do the contents of the two tubes compare? What is this condition called? How can the proportions be changed?
- \*18. Mention important uses of iodine and its compounds.
- \*19. Discuss occurrence of fluorine compounds in nature.
- \*20. How may fluorine be prepared?
- \*21. Give the physical and chemical properties of the element with equations for reactions.
- \*22. How may  $\text{HF}$  be prepared? Give equation for reaction. How is the aqueous solution preserved? Mention important uses.
- 23. Define association with reference to aqueous solutions of  $\text{H}_2\text{F}_2$ .

\*24. State the physical and chemical properties of  $\text{H}_2\text{F}_2$  solution, mentioning especially one which is important commercially and giving equation for reaction.

\*25. How would you test for iodine? For bromine? For fluorine?

\*26. How does the reaction of the Cl ion differ from that of the Br ion with  $\text{AgNO}_3$ ?

27. Outline the properties of  $\text{F}_2$ ,  $\text{Cl}_2$ ,  $\text{Br}_2$  and  $\text{I}_2$ , also noting acids formed.

\*28. What is the order of activity of the halogens?

29. Do the halogens form compounds with each other?

30. Mention two kinds of containers used for storing  $\text{H}_2\text{F}_2$ . Of what do stills and condensing worms in  $\text{H}_2\text{F}_2$  factories consist? Why take such precautions in the manufacture and storage of the acid?

\*31. Figure the percentage composition of fluorspar and cryolite.

\*32. How and why do methods for the preparation of HI and HBr differ from that of HCl? Give equations for reactions for both.

33. Write five equations each involving a different halogen acid with a different base.

\*34. One kilogram of bromine occupies 3180 cc. What is its specific gravity?

\*35. How would you treat a patient who had inhaled too much bromine or chlorine?

\*36. How much phosphorus is necessary for the preparation of a gram-molecular volume of HBr?  $\text{H}=1.008$ ,  $\text{Br}=79.92$ ,  $\text{P}=31.04$ . If the dry HBr were heated in a tube and partly decomposed into its constituents what volume change would result?



## 16. DISSOCIATION IN SOLUTION

- \*1. Mention the characteristic properties of acids when in aqueous solutions; of bases; of salts. Illustrate by equations.
- \*2. Compare the effect of causing two substances to react by heating a dry pulverized mixture, with their reactions in aqueous solution.
- \*3. How do undissociated substances in solution in water affect the freezing point? Is the effect the same on all solvents? What influence does dissociation or ionization have on the freezing point?
- \*4. How do undissociated substances in solution in water affect the boiling point? Is the effect the same for all solvents? How does dissociation influence the results?
- \*5. What influence will associated and undissociated substances in solution have on the osmotic pressure? Ionized substances?
- \*6. How will a  $\frac{1}{100}$  molar weight of sugar in a liter of water affect conditions mentioned in questions 3, 4 and 5? Assuming complete ionization what will be the effect of a  $\frac{1}{100}$  molar weight of HCl, NaCl, NaOH,  $\text{H}_2\text{SO}_4$ ,  $\text{MgSO}_4$ ,  $\text{BaCl}_2$ ,  $\text{AlCl}_3$ ,  $\text{H}_3\text{PO}_4$ ?
- \*7. A liter solution of NaOH causes a depression of the freezing-point of water of  $.93^\circ$ . Calculate the weight of NaOH present assuming complete dissociation.
- \*8. Calculate the depression of the freezing-point caused by dissolving 10 g. alcohol,  $\text{C}_2\text{H}_5\text{OH}$ , in 1 liter of water assuming no dissociation.  $\text{C}=12.005$ ,  $\text{H}=1.008$ ,  $\text{O}=16$ .



## 17. OZONE AND HYDROGEN PEROXIDE

1. Discuss the history and occurrence of ozone.
- \*2. Describe a simple electrical method for the preparation of ozone and prepare a sketch of the apparatus used.
3. Mention other methods for the preparation of ozone.
- \*4. Give the physical properties of ozone.
- \*5. Give the chemical properties of ozone with equations for reactions.
- \*6. Describe two tests for ozone. What precautions are necessary in one of these to distinguish ozone from other substances which might produce a similar effect?
- \*7. Discuss the activity of oxidizing agents and account for the relative activity of oxygen and ozone.
- \*8. Define allotropism and give the allotropic forms of oxygen.
9. Compare the physical and chemical properties of ozone with those of oxygen.
- \*10. How can you prove the formula for ozone by applying Gay-Lussac's law to phenomena observed in its formation from oxygen?
- \*11. Mention the most important uses of ozone.
12. Discuss the occurrence of hydrogen peroxide.
- \*13. Describe several methods for the preparation of  $\text{H}_2\text{O}_2$  giving equations for reactions.
- \*14. What precautions are necessary in the concentration of  $\text{H}_2\text{O}_2$  solutions and why?
- \*15. Give the physical and chemical properties of  $\text{H}_2\text{O}_2$  and its aqueous solution.
- \*16. How can you prove that the formula is  $\text{H}_2\text{O}_2$  and not  $\text{HO}$ ?
- \*17. Describe a good test for  $\text{H}_2\text{O}_2$ .
- \*18. Mention several reactions which prove that  $\text{H}_2\text{O}_2$  is an oxidizing agent. How might one of these be utilized for whitening "white lead" paints which have darkened in manufacturing districts?
- \*19. Mention the principal uses of  $\text{H}_2\text{O}_2$  solution comparing the action in certain cases with that of  $\text{Cl}_2$ . Describe an experiment which illustrates this action by the former agent.
- \*20. Define oxidation; reduction; oxidizing agent; reducing agent. Give examples of each.
- \*21. Show by equations that in the presence of  $\text{KMnO}_4$  and  $\text{H}_2\text{SO}_4$ ,  $\text{H}_2\text{O}_2$  acts as a reducing agent and indicate where the reduction takes place.
- \*22. Calculate the freezing point of a 3 per cent solution of  $\text{H}_2\text{O}_2$ .  $H = 1.008$ ,  $O = 16$ .



\*23. What volume of oxygen, measured at 20° C. and 730 mm., will be evolved by 50 g.  $\text{H}_2\text{O}_2$  in the reaction discussed in question 21?  $\text{H}=1.008$ ,  $\text{O}=16$ ,  $\text{S}=32.06$ ,  $\text{K}=39.10$ ,  $\text{Mn}=54.93$ .

\*24. State the law of multiple proportions and show how it applies to compounds of oxygen and hydrogen.

25. How would you attempt to prove that water is  $\text{H}_2\text{O}$  and hydrogen peroxide  $\text{H}_2\text{O}_2$ ?

\*26. Define "nascent" oxygen. Describe an experiment which shows the difference of behavior of nascent and molecular oxygen.

27. Why is hydrogen peroxide not sold in concentrated solution? What are the impurities which lower its stability? Mention substances frequently introduced into the commercial 3 per cent  $\text{H}_2\text{O}_2$  to preserve it?

## 18. IONIZATION

- \*1. Define electrolyte; non-electrolyte. Give several examples of each. Which of these conduct electricity and how is this property accounted for?
- \*2. How do the above two classes of substances in solution affect the freezing-point of the solvent and why?
- \*3. Distinguish between conductors and electrolytes and give examples.
- \*4. Define electrolysis and give examples.
- \*5. Mention three states in which substances are liberated at the electrodes and illustrate by examples.
- \*6. Do substances in solution necessarily dissociate into ions? Give examples to illustrate your answer.
- \*7. Define primary product; secondary product in electrolysis. Give examples.
- \*8. Describe an experiment which shows that ions migrate and indicate their directions.
- \*9. Do all ions travel at the same speed? Give the relative rates for a few.
- \*10. State Faraday's law and illustrate by examples.
- \*11. How might the passage of a current through an ionized solution be explained?
- \*12. Compare the chemical and physical properties of the ion of any element with those of its atoms or molecules.
- \*13. How does the stability of dry substances compare with their stability in solution? Give examples.
- \*14. Do ions recombine to form molecules in solution? What happens when equilibrium is established?
- \*15. Define electron. How does the mass of the electron compare with that of the hydrogen atom? What happens to an atom when it loses an electron? When it gains one? Illustrate by examples.
- \*16. Define oxidation and reduction in terms of electrons gained or lost. Give examples.
- \*17. Define ion; ionization. Give examples of each. To which three classes of substances are ionogens confined? Define cation; anion. To which electrode is each carried? What is its own charge? The charge of the electrode? Define anode; cathode.
- \*18. Define coulomb; ampere. How many coulombs are required to liberate 1.008 g. hydrogen at the cathode?
- \*19. Define ionic equilibrium and discuss the ion-product-constant, illustrating by a recent laboratory experiment. How do temperature and pressure or concentration affect the value?
- \*20. Describe an experiment which proves that the degree of electrical conductivity depends on degree of ionization.
- \*21. Do all electrolytes ionize to the same extent? Give examples. How does dilution affect the relative values for two substances having markedly different degrees of ionization in fairly concentrated solutions?
- \*22. Discuss the relationship existing between degree of ionization and chemical activity.





## 19. IONIC SUBSTANCES AND THEIR INTERACTIONS

- \*1. What are the three classes of ionogens? How are they further classified on the basis of the number of  $H^+$  or  $(OH)^-$  ions contained? Give examples.
- \*2. What is a double salt? How do double salts ionize? Give examples.
- \*3. How do the properties of ions compare with those of the elementary substances in the free state? Give examples. How would you test for  $Cl^-$ ?  $Cl_2$ ?
4. Discuss ionic equilibrium in the case of single ionogens and write a number of equations to illustrate same.
- \*5. What is meant by "Displacement of Ionic Equilibrium?" Give examples of effects due to dilution; addition of one of the reacting substances; removal of one of the reacting substances. Mention three states in which a resultant (reaction product) may be removed giving an example of each.
- \*6. Define double decomposition and illustrate by an ionic equation. How does the thermal effect function here?
- \*7. How would you explain precipitation on the basis of ionic and molecular equilibrium?
- \*8. Write an ionic equation for a case of neutralization of a base by an acid. What energy effect would you expect in all such cases?
- \*9. Define acid; base; salt; acid salt; basic salt. Give examples of each.
- \*10. Define normal solution in terms of ionizable constituents of the solutes. How do equal volumes of normal solutions of bases and acids react? What results.
- \*11. What is the electromotive series? Discuss the displacement of one metal by another of this basis and give equations for a number of reactions.



## STUDY QUESTIONS FOR INORGANIC CHEMISTRY

### 20. SULPHUR AND HYDROGEN SULPHIDE

- \*1. Discuss the occurrence of sulphur in nature both free and in combination.
- \*2. Discuss the preparation of sulphur from its ores, including methods of mining and purification and the various forms sold on the market.
- \*3. Give the physical and chemical properties of sulphur.
- \*4. Describe the allotropic forms of sulphur and state how they are obtained.
- \*5. Give the chemical properties of sulphur with equations for reactions.
- \*6. Mention the principal uses of sulphur.
- \*7. Describe the most important method for the preparation of  $\text{H}_2\text{S}$ . Also give one other method.
- \*8. Give the physical properties of  $\text{H}_2\text{S}$ .
- \*9. Give the chemical properties of  $\text{H}_2\text{S}$  with equations for reactions.
- \*10. Discuss the aqueous solution of  $\text{H}_2\text{S}$  with respect to solubility, degree of ionization, and strength as an acid. How do its salts with strong bases react with indicators in aqueous solutions? Why? Prepare ionic equations which account for this.
- \*11. Define dibasic acid and illustrate in the case of  $\text{H}_2\text{S}$ .
- \*12. Why does  $\text{H}_2\text{S}$  water turn cloudy when exposed to air?
- \*13. Show by equations how  $\text{H}_2\text{S}$  reacts with  $\text{K}_2\text{Cr}_2\text{O}_7$  in  $\text{HCl}$  solution. How do the valence and position change for Cr? What is an agent which acts like  $\text{H}_2\text{S}$  in this instance called?
- \*14. Define hydrolysis and illustrate in the case of  $\text{Na}_2\text{S}$ .
- \*15. What is a polysulphide and how may it be prepared?
- \*16. Account for the liberation of  $\text{H}_2\text{S}$ , by the action of an aqueous solution of  $\text{HCl}$  on  $\text{FeS}$ , on the basis of degree of ionization and solubility.
- \*17. What is the ion product constant formula for  $\text{H}_2\text{S} \rightleftharpoons \text{H}^+ + \text{HS}^-$  in aqueous solution.  
For  $\text{NaCl} \rightleftharpoons \text{Na}^+ + \text{Cl}^-$   
For  $\text{FeCl}_3 \rightleftharpoons \text{Fe}^{+++} + 3\text{Cl}^-$
- \*18. Discuss the various classes of metallic sulphides with respect to solubility in acids. How is this utilized in analytical chemistry?
- \*19. How may the sulphides of metallic elements, whose sulphides are hydrolyzed by water, be prepared?
- \*20. What is the valence of sulphur towards most metallic elements? Towards hydrogen? Towards oxygen? Write the structural formulas for hydrogen sulphide, ammonium hydrogen sulphide, sodium sulphide, ferrous sulphide, arsenious sulphide, sulphur dioxide, sulphur trioxide.
- \*21. Account for the tarnishing of metals and discoloration of paints in manufacturing districts. Suggest a method for remedying the paint difficulty.
- \*22. Give a method of testing for  $\text{H}_2\text{S}$  together with the principal uses of the gas.





## 21. OXIDES AND OXYGEN ACIDS OF SULPHUR

- \*1. Describe two commercial methods for the preparation of  $\text{SO}_2$ , giving equations for reactions.
- \*2. Describe the two most important laboratory methods for the preparation of  $\text{SO}_2$  giving equations for reactions.
- \*3. Write the equations for the following reactions balancing by positive and negative valences:  
     Copper+conc. sulphuric acid.  
     Sulphuric acid+hydriodic acid.  
     Manganese dioxide+hydrochloric acid.  
     Sulphuric acid+hydrogen sulphide.  
     Phosphorus+bromine+water.
- \*4. Give the physical properties of  $\text{SO}_2$  and its aqueous solution.
- \*5. Give the chemical properties of  $\text{SO}_2$  and its aqueous solution with equations for reactions.
- \*6. Mention the principal uses of  $\text{SO}_2$  with advantages over  $\text{Cl}_2$  in certain cases. Also mention the most important salts of  $\text{H}_2\text{SO}_3$  and give their uses.
- \*7. Define critical temperature; critical pressure. Discuss the liquefiability of gases mentioning some which are easily liquefied and others which present difficulties.
- \*8. Discuss the solubility of gases mentioning three classes and giving an example for each.
- \*9. Give the most important methods for converting  $\text{SO}_2$  to  $\text{SO}_3$ . Is the temperature a factor? Mention the best temperature and write the thermal equation for the reaction.
- \*10. Define "catalytic agent." Mention a number of contact agents which hasten the oxidation of  $\text{SO}_2$ . Recall other reactions where catalytic agents were employed.
- \*11. How are impurities in substances treated apt to influence catalytic action? Give example.
- \*12. Give the physical properties of  $\text{SO}_3$ .
- \*13. Give the chemical properties of  $\text{SO}_3$ , with equations for reactions.
14. List the oxygen acids of sulphur and give their names.
- \*15. Describe the chamber process for the manufacture of  $\text{H}_2\text{SO}_4$  and give equations for reactions.
- \*16. Describe the contact process (Knietzsch, 1901) for the manufacture of  $\text{H}_2\text{SO}_4$  and give equations for reactions.
- \*17. How may pyrosulphuric acid (sometimes called fuming or Nordhausen acid) be prepared? Give equations for reactions. What forms when this is added to water?

- \*18. Give the physical properties of  $\text{H}_2\text{SO}_4$ .
- \*19. Give the chemical properties of concentrated and dilute  $\text{H}_2\text{SO}_4$  with equations for reactions.
- \*20. Define dibasic acid and give two other examples besides  $\text{H}_2\text{SO}_4$ . Give formulas for their salts.
- \*21. How does concentrated  $\text{H}_2\text{SO}_4$  react with water? How does this tendency in  $\text{H}_2\text{SO}_4$  cause it to react with sugar, starch, etc.? Why is the strong acid valuable as a drying agent? Which gases studied thus far can be dried by bubbling through conc. sulphuric acid?
- \*22.  $\text{H}_2\text{SO}_4$  is said to be an oxidizing agent. Write equations for a number of reactions which illustrate this.
- \*23. Mention the most important uses of concentrated and dilute  $\text{H}_2\text{SO}_4$ . Why is the concentrated acid employed in the preparation of other acids from their salts?
- \*24. Does the aqueous solution have the same properties as conc.  $\text{H}_2\text{SO}_4$ ? Compare the properties and account for differences.
- \*25. Describe the test for the sulphate ion and give equation for reaction.
26. What is the law of consecutive or successive reactions.
- \*27. How may sodium thiosulphate ("hypo") be prepared? Give equation for reaction. Mention an important use.
28. How may persulphuric acids and persulphates be prepared? Give equations for reactions.
29. Discuss the chlorine compounds of sulphur and give equations for reactions involved in their preparation.
- \*30. Write structural formulas for  $\text{H}_2\text{SO}_3$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{SO}_2\text{Cl}_2$ ,  $\text{SO}_2$ ,  $\text{SO}_3$ . What is the more modern view regarding their structure?
- \*31. 1199.6 kilograms of pyrites is roasted for the manufacture of sulphuric acid by the contact process. If both the  $\text{SO}_2$  and  $\text{SO}_3$  were perfect gases what volume would they occupy under standard conditions? At  $27.3^\circ$  under a pressure of 836 mm.?  $\text{Fe} = 55.84$ ,  $\text{S} = 32.06$ .



## STUDY QUESTIONS FOR INORGANIC CHEMISTRY

### 22. SELENIUM, TELLURIUM

1. Discuss the occurrence of selenium and its compounds in nature.
2. How may the element be prepared from its compounds? Give equations for reactions.
3. Give the physical properties of selenium.
4. Give the chemical properties of selenium with equations for reactions.
- \*5. Mention the most important uses of the element.
6. Discuss the occurrence of tellurium and its compounds in nature.
7. How may tellurium be prepared?
8. Give the physical and chemical properties of tellurium.
9. Prepare a tabular outline showing the following for sulphur, selenium and tellurium:—atomic weight; molecular formula of solid; color; melting point; solubility; hydrogen compound; oxygen compound; oxygen acids.

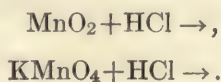
### PERIODIC ARRANGEMENT OF THE ELEMENTS, Etc.

- \*10. Define metallic element; non-metallic element. Give five examples of each. To which class do the positive elements belong? The negative ones?
- \*11. Mention the classes of compounds formed by metallic elements; by non-metallic elements. What are some of the general properties which characterize each class?
12. Give the historical developments which lead up to the Mendelejeff arrangement of the elements.
- \*13. Describe the Mendelejeff periodic table, discussing the arrangement as to atomic weights, valence, metals and non-metals, basicity and acidity, properties of groups, properties of families, length of series.
- \*14. Mention some irregularities encountered in the Mendelejeff table.
- \*15. Has the arrangement served to predict the discovery of elements, unknown at the time of its preparation? Name one or two. How did the properties compare with the predicted ones?
- \*16. Why were the zero and eighth groups added?
- \*17. Discuss Moseley's arrangement by atomic numbers. How do the wave lengths of the various elements compare with their atomic weights? How are the atomic numbers derived from the wave lengths of the characteristic spectra? How are the atomic numbers related to atomic weights?
- \*18. Mention a number of irregularities encountered in the Mendelejeff arrangement which have been corrected in the Moseley arrangement.
19. What are X-rays, and how are the X-rays of the various elements produced?
- \*20. What is an electron? How does its mass compare with that of the positive nucleus of the hydrogen atom? How does the size of the nucleus compare with that of the electron?
21. What is the atomic structure of a cubical crystal of salt? By whom, when and how was this determined? How and why does the structure change when crystals melt, dissolve or vaporize?



## 23. OXIDES AND OXYGEN ACIDS OF CHLORINE—OXIDATION AND REDUCTION

- \*1. Give the formulas for hypochlorous, chloric and perchloric acids, together with formulas and names of their sodium salts.
- \*2. Describe two laboratory methods for the preparation of hypochlorites and give equations for reactions.
- \*3. How may hypochlorous acid be prepared from its salts? What are the properties of the acid? Give equations for reactions.
- \*4. Describe the most important commercial method for the preparation of calcium hypochlorite. How is the acid liberated from this? Give equations for reactions.
- \*5. Discuss the oxidizing power of  $\text{HClO}$ . How does it compare with that of  $\text{O}_2$ ? Why?
- \*6. Discuss the bleaching properties of  $\text{HClO}$ . Are its uses limited or can it be employed for all fibers? Why?
- \*7. Discuss the use of hypochlorites as disinfecting agents.
- \*8. Why is chlorine itself not considered a bleaching agent?
- \*9. How is potassium chlorate prepared? Give equations for the successive reactions.
- \*10. Mention the principal uses of  $\text{KClO}_3$ . On what do they depend?
- \*11. How may potassium perchlorate ( $\text{KClO}_4$ ) be prepared? How can it be separated from the  $\text{KClO}_3$ ? How may  $\text{HClO}_4$  be prepared from the salt? Give equations for reactions.
- \*12. State the law of consecutive reactions and give several examples of its application.
- 13. How may  $\text{HBrO}$ ,  $\text{HBrO}_3$  and  $\text{HIO}_3$  be prepared?
- \*14. Give the structural formulas for  $\text{HCl}$ ,  $\text{HClO}$ ,  $\text{HClO}_3$ ,  $\text{HClO}_4$ .
- \*15. Write several equations for reactions in which free oxygen serves as an oxidizing agent; where combined oxygen serves the purpose.
- \*16. Write an equation for a reaction where  $\text{Cl}_2$  serves as an oxidizing agent.
- \*17. How does oxidation affect the valence in reactions? Give examples.
- \*18. How may oxidation and reduction be interpreted on the basis of the electron theory?
- \*19. Discuss the use of positive and negative valences in the making of equations. Balance the following equations by this method:







## 24. THE ATMOSPHERE. THE HELIUM FAMILY

\*1. What is the pressure of the atmosphere per square centimeter on the Earth's surface? Per square inch? How may it be measured?

\*2. Mention three classes of components of the atmosphere and list those which belong to each class.

\*3. Discuss the presence of moisture in the air. How may it be removed? How may it be determined?

4. Describe the dry and wet bulb thermometer. Define humidity; dew point.

5. Describe the Hygrodeck and mention advantages possessed by the instrument.

\*6. Discuss the presence of carbon dioxide ( $\text{CO}_2$ ) in the air. How may it be detected? How may it be removed? How may it be determined? Write equations for reactions.

\*7. How much oxygen is present in air by volume? By weight? How may it be removed completely? How may it be determined? Give equations for reactions.

\*8. How much nitrogen is present in air by volume? By weight? How may this be removed after the moisture, carbon dioxide and oxygen have been taken out? Give equation for reaction.

\*9. Discuss the carbon dioxide cycle in nature.

\*10. Discuss the oxygen cycle in nature.

\*11. Discuss the nitrogen cycle in nature.

\*12. Why is the barometer reading lower on a moist day than on a dry day? To what is the discomfort experienced in warm weather due? That experienced in warm rooms heated by warmed air during cold weather?

\*13. What effect do  $\text{CO}_2$  and volatile organic compounds from expired air have? What are the aims of ventilation?

\*14. Discuss the presence of dust, bacteria, etc., in air. To what can you attribute fogs?

\*15. Give the composition, by volume, of normal air.

\*16. Give several proofs that air is a mixture and not a compound.

\*17. Discuss the principle involved in liquefying gases.

18. Describe the Hampson process for liquefying air.

\*19. Describe the Dewar flask and state the principle which makes it valuable as a container for storing liquid air? Why is it sometimes silvered?

**\*20.** Discuss the composition and properties of liquid air and its effect on various substances immersed in the liquid.

**\*21** How was argon discovered? How does it differ from nitrogen? To which group in the Mendeleeff table does it belong and why?

**\*22.** Discuss helium as to discovery in the Sun's chromosphere and on earth. What is its origin in uranium minerals? To which group does it belong in the Mendeleeff system? How does it function in the evolution theory of the formation of other elements?

**\*23.** Describe the Plücker tube and state the principle involved. How is it operated?

**\*24.** How may the other members of the zero group, neon, krypton, xenon and niton, be obtained and recognized?



## 25. NITROGEN AND AMMONIA

1. Discuss the history of nitrogen.
- \*2. What is the maximum valence of nitrogen towards hydrogen? Towards oxygen?
- \*3. Discuss the occurrence of nitrogen in nature both free and in combination.
- \*4. Describe a safe laboratory method for the preparation of  $N_2$ , preparing a neat sketch of the apparatus used. Write equations for reactions.
- \*5. Give the physical properties of  $N_2$ .
- \*6. Give the chemical properties of  $N_2$  with equations for important reactions.
- \*7. Discuss the "nitrogen cycle" in nature.
- \*8. Discuss the commercial manufacture of ammonia from coal.
9. What are some possible sources of ammonia in the United States, where this valuable by-product is largely wasted at present? What is the source in Scotland? Has the ammonia recovery been of value in this connection? How did it save an industry which suffered from foreign competition?
- \*10. Discuss the process for synthesizing ammonia used by the Badische Company as to temperature required, decomposition temperature, pressure, contact agent. Why is pressure required? What is the source of the hydrogen? Of the nitrogen?
- \*11. State Van't Hoff's Law and show how it applies in the synthetic production of  $NH_3$ .
- \*12. State LeChatelier's law and show how it applies in the synthetic production of  $NH_3$ .
- \*13. Give the most economical laboratory method for the preparation of ammonia from one of its salts by the action of a base. Write equation for reaction.
- \*14. How may ammonia be prepared quickly and conveniently in the laboratory?
- \*15. Give the physical properties of  $NH_3$ .
- \*16. What can you say regarding the solubility of  $NH_3$  in water? Describe a laboratory experiment which proves this. What is the strength and specific gravity of "concentrated ammonia"?
- \*17. Why can ammonia be used in refrigeration? What could be used as a substitute? Describe the process of ice manufacture.
- \*18. Define molecular association and give examples for two different substances. Define molecular dissociation and mention two methods by which this may be accomplished.
- \*19. Define heat of vaporization; heat of fusion. Give examples.
- \*20. Why can calcium chloride solution be used as a brine in ice manufacture? What advantage has it over salt water?
- \*21. Mention two important uses (other than refrigeration) of ammonia and its compounds.
- \*22. Discuss the chemical properties of ammonia. Write equations for reactions.



## 26. OXIDES AND OXYGEN ACIDS OF NITROGEN

- \*1. List the oxides and oxygen acids of nitrogen together with their sodium salts and name each compound.
- \*2. State the law of constant or definite proportions; of multiple proportions. Give examples.
- \*3. Discuss the occurrence of nitrates in nature.
- \*4. Describe the commercial process for the manufacture of nitric acid ( $\text{HNO}_3$ ) from niter and write equations for reactions.
- \*5. Give the physical properties of  $\text{HNO}_3$ .
- \*6. Give the chemical properties of  $\text{HNO}_3$  with equations for important reactions.
7. Recall another case beside  $\text{HNO}_3$  where one obtains a constant boiling acid. How does pressure influence results?
- \*8. Give two methods for the preparation of nitric oxide ( $\text{NO}$ ) with equations for reactions. Which is the most important laboratory method?
- \*9. Give the physical and chemical properties of  $\text{NO}$ .
- \*10. Describe a delicate test for nitric acid.
- \*11. How may nitrogen tetroxide or peroxide ( $\text{NO}_2$ ) be prepared?
- \*12. Give the properties of  $\text{NO}_2$ .
- \*13. Discuss the manufacture of nitric acid from atmospheric nitrogen. Define endothermic change. Write the thermal reaction for the preparation of  $\text{NO}$  from  $\text{N}_2$  and  $\text{O}_2$ .
- \*14. Which metals in the electromotive series yield  $\text{H}_2$  when treated with  $\text{HNO}_3$ ? Which yield  $\text{NO}$ ? Give examples with equations for reactions.
- \*15. Show by equations how ammonium nitrate forms when  $\text{Zn}$  and  $\text{HNO}_3$  react.
16. How does concentration influence the action of  $\text{HNO}_3$  on copper? Illustrate with equations for reactions.
17. Show by equations, the action of dilute and concentrated  $\text{HNO}_3$  on sulphur.
- \*18. What is aqua regia? Write the equation for reaction which takes place when it breaks up. Mention a number of metals which dissolve in this mixture, but which are not attacked by any of the strong acids singly.
- \*19. Give two methods for the preparation of nitrites with equations for the reactions. How may nitrous acid ( $\text{HNO}_2$ ) be prepared from its salts?
20. Give the physical and chemical properties of  $\text{HNO}_2$ .



21. What are the properties of nitrous anhydride ( $\text{N}_2\text{O}_3$ )?
22. What is hyponitrous acid ( $\text{H}_2\text{N}_2\text{O}_2$ )?
- \*23. Describe a laboratory method for the preparation of nitrous oxide ( $\text{N}_2\text{O}$ ) and give equations for reactions.
- \*24. Give the physical, chemical and physiological properties of  $\text{N}_2\text{O}$ .
25. Write graphic or structural formulas for ammonium hydroxide, nitric acid, ammonium sulphate, sulphuric acid, ammonium nitrate, showing valence by gain or loss of electrons.
26. Discuss the following explosives as to mode of preparation and properties: Nitroglycerine, gun cotton, cordite, dynamite, ammonal, trinitrotoluene (T.N.T.), picric acid. What are their special uses?
27. How may celluloid, collodion and artificial silk be prepared? Mention uses.
- \*28. Write equations for reactions between Cu and dilute  $\text{HNO}_3$ ; Cu and conc.  $\text{HNO}_3$ , using (1) the positive and negative valence method and (2) the positive electrical charge plan for balancing.
- \*29. Define "nascent hydrogen" and describe an experiment which shows what is meant by the term "nascent" used in the chemical sense.
- \*30. Summarize the principal uses of the oxides and oxygen acids of nitrogen.
- \*31. Calculate the volume of nitrous oxide obtainable from 25 g. ammonium nitrate, measuring the gas at  $20^\circ$  under 750 mm. pressure.  $\text{N}=14.01$ ,  $\text{H}=1.008$ ,  $\text{O}=16$ .
- \*32. How much copper is necessary for the preparation of a gram-molecular volume of nitric oxide?  $\text{Cu}=63.57$ .
- \*33. Calculate the percentage composition of nitric acid.
- \*34. How do you account for the presence of nitric acid and ammonia in the atmosphere? Ammonium compounds and nitrates in the soil?
- \*35. Would it be possible to completely convert a mixture of oxygen and nitrogen, heated in a sealed tube, into the oxides of nitrogen? How is the difficulty overcome in the Birkeland-Eyde process?
- \*36. On the basis of the electron theory show graphically why  $\text{NH}_4\text{OH}$  is basic and  $\text{HNO}_3$  acidic.
- \*37. How do nitrates behave when heated on charcoal? Why?

## 27. PHOSPHORUS

- \*1. How do phosphorus and nitrogen resemble each other in their compounds?
- \*2. Discuss the occurrence of phosphorous compounds in nature.
- \*3. Describe the modern commercial method used for the manufacture of phosphorus giving equation for reaction. How does electricity function in the process?
- \*4. Give the physical properties of phosphorus.
- \*5. Give the chemical properties of phosphorus together with equations for important reactions.
- \*6. Discuss the manufacture of matches.
- \*7. How may phosphine ( $\text{PH}_3$ ) be prepared? Give equations for reactions. What are its properties? What causes the gas to ignite? Write the graphic formula of the salt formed.
8. How does  $\text{PH}_3$  resemble  $\text{NH}_3$ ? How do they differ?
- \*9. List the halogen compounds of phosphorus. How may  $\text{PBr}_3$  and  $\text{PCl}_3$  be prepared? What are their properties? How may  $\text{PCl}_5$  be prepared? Write equations for preparation of  $\text{PCl}_3$  and  $\text{PCl}_5$  and their hydrolysis.
- \*10. What are the two principal oxides of phosphorus? What happens when they react completely with an excess of water. Write equations for reactions. What are the correct formulas for the oxides and why?
- \*11. Outline the acids of phosphorus, giving their names, formulas and the oxides from which they are formed together with the number of molecules of water added in their formation.
- \*12. How may pyrophosphoric acid be prepared from orthophosphoric? Metaphosphoric from orthophosphoric? Phosphorus pentoxide from orthophosphoric acid? Illustrate by use of graphic or structural formulas and by equations.
- \*13. What is an acid anhydride? Give examples for cases encountered before studying the oxides of phosphorus.
- \*14. How may orthophosphoric acid be prepared economically from one of its salts? Give equation for reaction. How does the acid ionize? List the sodium salts of the acid. What is microcosmic salt?
- \*15. What are the tests for the orthophosphate ion. Give equations for reactions.
16. How may sodium pyrophosphate be prepared? Sodium metaphosphate?
- \*17. Mention an important laboratory use for sodium metaphosphate and give examples.
- \*18. Describe tests which identify ortho, pyro and metaphosphoric acid.

**\*19.** How may phosphorous acid be prepared? Write graphic formula for the acid.

**20.** How may hypophosphorous acid be prepared? Write graphic formula Also equation for reaction.

**21.** List the sulphides of phosphorus. How are they prepared? Which one is used in match manufacture?

**\*22.** Compare the compounds of phosphorus with those of nitrogen and sulphur.

**\*23.** When magnesium chloride reacts with di-sodium hydrogen orthophosphate in the presence of ammonium hydroxide it forms magnesium ammonium orthophosphate. This, on being heated forms magnesium pyrophosphate. Write equations for reactions involved and calculate the theoretical amount of the last-named compound formed if the original solution contained 1 g. of di-sodium hydrogen orthophosphate. What is the magnesium oxide equivalent of the pyrophosphate formed?

**\*24.** Define acid; base; salt; acid salt; basic salt; multibasic acid; multiacid base. Give examples of each.

**\*25.** Define oxidation; reduction. Give examples.



## 28. CARBON. CARBON MONOXIDE. CARBON DIOXIDE

- \*1. Discuss occurrence of carbon in nature, both free and in combination.
- \*2. Define allotropism. Give examples for three elements which you have studied thus far.
- \*3. Discuss the occurrence and theory of formation of the diamond.
- \*4. How may diamonds be prepared in the laboratory?
- \*5. Discuss the occurrence and theory of the formation of graphite.
- 6. Describe the commercial manufacture of graphite and state who discovered it and the method used to manufacture carborundum. Describe manufacture of carborundum ( $\text{SiC}$ ) and give properties and uses.
- \*7. Discuss occurrence and theory of formation of amorphous carbon (coal). Cite present-day facts which tend to corroborate your theory.
- \*8. Discuss the composition of various types of carbon found in nature from peat to diamond.
- \*9. Give physical and chemical properties of diamond, graphite and amorphous carbon in comparative outline.
- \*10. Describe a lecture experiment which proves the composition of diamond.
- \*11. Describe two methods for the production of coke. Which of these is most economical? Discuss the quality and use of the two types.
- \*12. How is charcoal prepared? Compare its by-products with those derived from coal in by-product coking.
- \*13. Give the principal uses of coke, charcoal, diamond and graphite.
- \*14. The specific gravity of charcoal is about 1.5. Why does it float on water?
- \*15. A sample of coal contains 84 per cent available carbon and 6 per cent available hydrogen. Calculate the volume of atmospheric air required to burn 1 kilogram. ( $\text{C}=12.005$ ,  $\text{H}=1.008$ .)
- \*16. What does the position of carbon in Group IV of the Periodic Table indicate? Show that these indications are borne out by facts regarding the allotropic forms and properties of the element.
- 17. What led Moissan to experiment on the production of diamond?
- \*18. From the heats of combustion of the various allotropic forms of carbon which would you consider the ultimate type?
- \*19. Discuss adsorption as it applies to amorphous carbon and give examples of gases, substances in solution, color and flavors as affected by this property. Is the adsorbing power equal for all gases?
- \*20. Give two methods for the preparation of carbon monoxide. Also equations for reactions.

- \*21. Give the physical and chemical properties of the gas.
- \*22. Give reactions to show that carbon is a reducing agent.
- \*23. Why is carbon monoxide a treacherous gas to use? What is added to water gas to guard against a mishap?
- \*24. Describe methods for the manufacture of water gas and producer gas and give equations for reactions.
- \*25. Discuss occurrence of carbon dioxide both free and in combination.
- \*26. Give one commercial and the most important laboratory method for its preparation, together with equations for reactions.
- \*27. Give the physical and chemical properties of carbon dioxide with equations for reactions. How may various carbonates be prepared in the laboratory? Write equations for reactions.
- \*28. What are the principal uses of  $\text{CO}_2$ ?
- \*29. Discuss relation of carbon dioxide to life. How is it indirectly responsible for many valuable fuels?
- \*30. Define normal, acid and basic salt giving examples for carbonates.
- \*31. How can you prove the composition of  $\text{CO}_2$  by a laboratory experiment?
- \*32. Describe the manufacture of calcium carbide and give its properties and uses.
- \*33. Calculate the percentage composition of magnesium carbonate.  $\text{Mg} = 24.32$ .
- \*34. How many liters of carbon dioxide (standard conditions) must be passed over red-hot carbon to yield 84.015 grams of carbon monoxide.  $\text{C} = 12.005$ .
- \*35. How can you prove that a volume of ethylene contains twice as much carbon as an equal volume of methane?
- \*36. Write the thermal equation for the conversion of carbon to carbon monoxide; to carbon dioxide; carbon monoxide to carbon dioxide.
- \*37. Discuss the carbon cycle and compare it with the oxygen, phosphorous and nitrogen cycles.
- \*38. Describe a calorimeter and state the principle on which its use depends.
- \*39. How is carbon disulphide ( $\text{CS}_2$ ) prepared? Carbon tetrachloride ( $\text{CCl}_4$ )? Mention properties and uses.
- \*40. Discuss the preparation, properties and uses of cyanides.
- \*41. Give reaction which takes place when baking powder is treated with water.
- \*42. How much air containing the normal amount of  $\text{CO}_2$  will completely precipitate 5 grams of barium hydroxide?  $\text{Ba} = 137.37$ .
- \*43. How may carbonyl chloride be prepared? Mention uses.
- \*44. To what is the poisonous effect of tobacco smoking partly attributed?
- \*45. Describe a new treatment for carbon monoxide poisoning. How does carbon monoxide affect blood?



29. HYDROCARBONS. ILLUMINANTS. FLAME

- \*1. Define organic chemistry; hydrocarbon.
2. Give two theories which account for the presence of methane in nature. What is natural gas?
- \*3. Give a brief account of the occurrence, methods of preparation, properties and uses of methane. Write equations for reactions.
- \*4. Same for ethylene.
- \*5. Why does acetylene require a special type of burner when used as an illuminant? How may the gas be prepared? Give equations for reactions.
- \*6. Discuss occurrence of petroleum in nature.
- \*7. Define fractional distillation and state what results when the method is applied to petroleum.
- \*8. Account for the difference in degree of luminosity of various gases. Which element seems to control candle power in the gas?
- \*9. Define combustion. Cite examples of combustion taking place in various media.
10. How may the formation of coal be looked upon as a process of slow combustion? Define spontaneous combustion; kindling temperature.
- \*11. Prepare sketch showing parts of a Bunsen burner and state the function of each part.
12. Describe a method for the prevention of explosions in mines when oil lamps are employed, accounting for the failure of the gases to explode. When is a Davy safety lamp not a safety lamp?
- \*13. Define oxidizing and reducing flame and give applications.
- \*14. Give the empirical formula for members of the Paraffin Series; the Ethylene Series; the Acetylene Series; the Benzene Series.
- \*15. What is a substitution product? Give an example.
16. Name two homologues of methane and give their formulas.
- \*17. Describe a method for utilizing a non-luminous gas for illuminating purposes.
- \*18. What can you say about the temperature of various parts of a flame? In which part would you heat an object if you wished to give it the maximum heat obtainable?
- \*19. In what proportions must oxygen be mixed with the following gases, or vapors considered as gases, for their complete combustion? Methane, ethane, ethylene, acetylene, benzene. Calculate the proportion of air necessary for same.
- \*20. Define saturated and unsaturated hydrocarbon and give examples with structural formulas.
- \*21. What is meant by "cracking" a hydrocarbon? What are the products?
- \*22. What is Blau gas? Oil gas? Pintsch gas?





30. CARBOHYDRATES AND RELATED SUBSTANCES

- \*1. Define carbohydrate and give several examples.
- \*2. What is cellulose? Discuss its use in the manufacture of paper.
- \*3. What is starch? How is it obtained from natural products? Is starch soluble in water?
- 4. Discuss the conversion of starch into glucose, dextrose or grape sugar. What is the effect of glucose on Fehling's solution? What name is applied to sugars which produce this effect?
- 5. What are two classes of sugars. Define monosaccharide. Disaccharide. Give two examples of each.
- \*6. Discuss the production of sucrose (cane sugar) in plants. How is it obtained commercially from natural products?
- \*7. Discuss the physical and chemical properties of sucrose.
- 8. What is caramel? Invert sugar? Mention uses of each.
- 9. Discuss the action of enzymes on certain sugars.
- \*10. Discuss alcoholic fermentation in connection with the manufacture of commercial alcohol. How may absolute alcohol be prepared from commercial ethyl alcohol?
- \*11. What is denatured alcohol? Mention two denaturing agents.
- \*12. How may acetic acid be prepared from ethyl alcohol? What is vinegar?
- \*13. What happens when wood is subjected to destructive distillation?
- \*14. Mention an important property of charcoal and bone black. Define adsorption and give examples.
- \*15. Give a method for the manufacture of coal gas, mentioning the uses of the by-products.
- \*16. Discuss the bee-hive and by-product coke ovens. Which is the more efficient?





### 31. ORGANIC ACIDS AND SALTS. ALCOHOLS, ESTERS. FOODS

- \*1. What is an organic acid? Give the general formula for the saturated series of mono-basic organic acids.
- \*2. Compare the degree of ionization of organic acids with that of the ordinary inorganic acids.
- \*3. Give the general formula for the series of saturated monohydric alcohols. What are the first two members of this series?
- \*4. Define ester and give several examples.
- \*5. Compare the formation of an ester with the neutralization of an acid by a base. Is the reaction in the formation of an ester reversible or does it go to completion? What means is used to drive the reaction to completion?
- \*6. Discuss the composition of fat; lard; butter; olive oil and cotton-seed oil.
- 7. Discuss the chemical properties of fats and oils.
- \*8. What is a soap? What difference is there between hard soap and soft soap?
- \*9. What are the chemical properties of soaps? Discuss these in connection with cleansing and the softening of water.
- \*10. Define colloidal suspension; dispersion; dialysis; emulsion.
- \*11. State the principle involved in the ultramicroscope. The Brownian movement.
- 12. Discuss the coagulation of colloidal suspensions.
- 13. Discuss the preparation of cyanogen ( $C_2N_2$ ) and write equations for reactions.
- \*14. Discuss the physical and chemical properties of  $C_2N_2$  and (HNC) hydrocyanic acid.
- 15. Give method of preparation of (KNCN) potassium cyanate with equation for reaction.
- 16. Define isomer. What happens when  $NH_4NCO$  is dissolved in warm water.
- \*17. Mention an important use for potassium thiocyanate (KCNS).
- 18. Define protein. Discuss the composition of several of the common animal foods.
- \*19. Discuss digestion in connection with starches, fats and proteins.
- \*20. What is meant by the fuel value of a food?



### 32. SILICON AND BORON

- \*1. Discuss the chemical relations of silicon and boron to the preceding element in Group IV of the Mendelejeff table.
- \*2. Discuss the occurrence of silicon compounds in nature.
3. How do you account for the difference in resistance to heat changes between silica and glass?
- \*4. Give physical and chemical properties of boron and silicon with equations for reactions.
- \*5. Discuss the allotropic forms of silicon. How may amorphous boron and silicon be converted into crystalline forms?
- \*6. What are the most important alloys and compounds of silicon?
7. Discuss briefly manufacture of glass and mention five substances which impart color, naming the color produced.
- \*8. Discuss the dehydration of silica with reference to its importance in analytical chemistry.
- \*9. List and name the acids of silicon, giving their graphic formulas.
- \*10. Discuss the weathering of feldspar and rocks containing feldspar.
- \*11. Compare the action of  $\text{H}_3\text{BO}_3$  and  $\text{H}_2\text{SiO}_3$  toward other acids in aqueous solutions with their action at very high temperatures.
12. Discuss briefly a method for the manufacture of china and porcelain.
13. Discuss briefly a method for the manufacture of brick.
14. Discuss briefly a method for the manufacture of sewer pipe.
- \*15. Give the method of preparation and properties of  $\text{SiF}_4$ .
- \*16. Give the method of preparation and properties of  $\text{SiH}_4$ .
- \*17. Describe a method for the manufacture of carborundum, giving equations for reactions.
- \*18. Define viscosity; glass.
- \*19. Name two alkalies, two bases and two acids which are introduced into the raw glass mixture or "batch" for glass making.
- \*20. How much carborundum can be made, theoretically, from one ton of sand? Calculate percentage composition of carborundum, of sodium silicate.  $\text{Si}=28.3$ ,  $\text{C}=12.005$ ,  $\text{Na}=23$ .
21. Mention a substance which will remove the green color imparted to glass by iron. How do you account for the action?



\*22. Define precipitate, colloidal solution, molecular solution and distinguish between these by two methods.

\*23. Describe the silica garden. What is the term which is applied to this phenomenon? Why the difference in rate of growth of various "plants" in the silica garden?

\*24. Mention the principal uses of water glass and give its composition.

\*25. Define osmosis. Is osmotic pressure a function of molecular weight and ionization? Illustrate.

\*26. Discuss the occurrence of boron in nature.

\*27. Give methods for the preparation of boron from its compounds together with equations for reactions.

\*28. State a use to which the borax bead is put and give four examples of its application.

\*29. Give two important tests for boric acid or its compounds.

\*30. Mention important uses of boron and its compounds.

31. Write structural formulas showing transformation of boric acid into ortho and meta acid. Also for formation of  $B_2O_3$  from tetraboric acid.

\*32. Define hydrolysis and give several examples. Why does borax give an alkaline reaction in aqueous solution? Write the ionic equation for the reaction.

33. What is sodium perborate? How may it be prepared? Mention the principal uses.

34. Prepare a brief account of the borax industry in California.

\*35. Calculate the per cent of boron in borax containing full water of crystallization.  $B=11$ ,  $Na=23$ ,  $H=1.008$ .

36. Calculate the theoretical amount of magnesium for the preparation of 5 grams of boron from the trioxide.  $Mg=24.32$ .

\*37. How does the method for preparation of boric acid resemble that used for nitric acid and hydrochloric acid? Account for the fact that the same substance liberates all three.

\*38. Why is borax used as a flux in welding metals?

39. How do you account for the swelling of borax when heated?

\*40. Define calcination and lixiviation and give examples.

\*41. How does borax serve as a water softening agent?

42. Calculate the theoretical amount of fluorspar required to give enough hydrogen fluoride (action of  $H_2SO_4$ ) to convert 2 grams of silica to tetrafluoride.  $Ca=40.07$ ,  $F=19$ ,  $S=32.06$ .

\*43. Define dialysis and give examples.

### 33. THE BASE-FORMING ELEMENTS

\*1. Define luster; crystalline form; specific gravity; light metal; heavy metal; malleability; ductility; tenacity; hardness. Give examples of each.

\*2. Define melting-point; fusion; boiling-point; alloy; amalgam; electrical conductivity. Give examples of each.

\*3. Define ion; ionogen; complex ion; base; acid; weak base; weak acid; positive radical; negative radical; hydrolysis. Give examples.

\*4. Compare the general physical and chemical properties of metals and non-metals.

\*5. How do the chlorides, sulphates and nitrates of strong bases in solution, behave towards indicators? Solutions of salts of strong bases and weak acids? Of weak bases and strong acids? Account for the behavior of the last two classes and write ionic equations to illustrate same.

6. How do solutions of salts of weak bases with weak acids behave? Why?

\*7. Define ore; native state; metallurgy; flux; slag; electrolysis; amalgamation; aluminothermy. Give examples.

\*8. Discuss the occurrence of compounds of metals in nature.

\*9. Compare the natural occurrence of metals and non-metals.

\*10. Discuss the occurrence of metals in nature both free and in combination. How do you account for the fact that some metals occur as such and others are found only in their compounds? Mention five compounds of metals commonly found in nature.

\*11. Discuss methods for obtaining metals from their ores.

\*12. Discuss the following compounds of metals as to their solubility in water: Oxides, hydroxides, chlorides, sulphides, carbides, nitrates, sulphates, carbonates, phosphates, silicates.

\*13. Calculate the hydrogen equivalent of Mg, Al, K, Ba, Zn, Ag, Bi, Pt, Li.

\*14. How much coke should theoretically be required for the reduction of 2000 kilograms of  $\text{Fe}_2\text{O}_3$  if Fe and CO are the reduction products? If Fe and  $\text{CO}_2$  are the products? Fe = 55.84, C = 12.005.





## STUDY QUESTIONS FOR INORGANIC CHEMISTRY

### 34. POTASSIUM AND AMMONIUM

- \*1. List the metals of the alkali group in the order of their atomic weight. What are the characteristic properties of these elements?
- \*2. Discuss the occurrence of potassium compounds in nature.
- \*3. How may potassium be prepared from its compounds?
- \*4. Give the physical and chemical properties of potassium with equations for reactions.
- \*5. Discuss the halides of potassium.
- \*6. How may KOH be prepared? Give equations for reactions. What are its properties and uses?
- 7. How may  $K_2O$  and  $K_2O_4$  be prepared?
- \*8. Discuss the preparation, properties and uses of  $KClO$ ,  $KClO_3$  and  $KClO_4$ .
- \*9. Discuss the preparation, properties and uses of  $KNO_3$ .
- \*10. Discuss the preparation, properties and uses of  $K_2CO_3$ .
- \*11. Discuss the preparation, properties and uses of  $KCN$ .
- \*12. Discuss the preparation, properties and uses of  $K_2SO_4$ ; of  $KHSO_4$ .
- 13. How may the sulphides and polysulphides of potassium be prepared? What are their properties?
- \*14. Describe two tests for potassium in its compounds.
- 15. Discuss briefly the rare alkalis rubidium and caesium.
- \*16. Discuss the occurrence of ammonia in nature.
- \*17. Discuss the preparation, properties and uses of  $NH_4Cl$ ;  $NH_4NO_3$ ;  $(NH_4)_2SO_4$ ;  $(NH_4)_2S$ .
- \*18. How may ammonium amalgam be prepared and what does its formation seem to indicate?
- \*19. Describe three tests for ammonia in its compounds.
- \*20. How does the spectroscope serve for the detection of K, Rb, Cs? Mention an element whose presence in the chromosphere of the sun was indicated by the spectroscope before the discovery of that element in the earth.
- 21. What are the Fraunhofer Lines. How do you account for same?
- 22. Of what service has the spectroscope been to astronomy?
- \*23. Compare the solubility of alkali salts with those of other metals.
- \*24. State DuLong and Petit's law. How does it serve in checking atomic weights?
- \*25. If potassium vapor is monatomic, what is the weight of a gram-molecular volume corrected to standard conditions?
- \*26. Why does KCl not change the color of neutral litmus and  $K_2CO_3$  turn it blue? Write ionic equations for reactions.
- \*27. If there is complete evolution, what volume of  $CO_2$  will result, standard conditions, if 46.068 g. potassium carbonate is treated with  $H_2SO_4$ .  $K=39.10$ ,  $C=12.005$ ,  $O=16$ .



### 35. SODIUM AND LITHIUM. IONIC EQUILIBRIUM

- \*1. Discuss the occurrence of sodium compounds in nature.
- \*2. Describe the modern electrolytic preparation of sodium preparing a sketch of the apparatus used.
- \*3. Give the physical and chemical properties of sodium together with equations for reactions.
- \*4. Discuss the preparation, purification, properties and uses of NaCl.
- \*5. Discuss the preparation, properties and uses of NaOH, Na<sub>2</sub>O<sub>2</sub>, NaNO<sub>3</sub>.
- \*6. Describe the LeBlanc process for the manufacture of Na<sub>2</sub>CO<sub>3</sub>, giving equations for reactions involved.
- \*7. Describe the Solvay process for the manufacture of NaHCO<sub>3</sub> and Na<sub>2</sub>CO<sub>3</sub> with equations for reactions involved.
- \*8. Give the properties and uses of Na<sub>2</sub>CO<sub>3</sub> and NaHCO<sub>3</sub>.
- \*9. Discuss the chemistry of baking powders.
- 10. Discuss the preparation, properties and uses of Na<sub>2</sub>SO<sub>4</sub>·10H<sub>2</sub>O, Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>·5H<sub>2</sub>O, Na<sub>2</sub>HPO<sub>4</sub>·12H<sub>2</sub>O, NaPO<sub>3</sub>, Na<sub>2</sub>B<sub>4</sub>O<sub>7</sub>·10H<sub>2</sub>O.
- \*11. Give two tests for the sodium ion.
- 12. Discuss the occurrence of lithium compounds in nature.
- \*13. Mention a property which characterizes lithium compounds.
- \*14. Define ionic equilibrium; repression of ionization. Give examples to illustrate.
- \*15. Define ion product constant giving the formula and examples of its application.
- \*16. Discuss saturated solutions with respect to degree of ionization and the ion product constant formula.
- \*17. On above basis account for the precipitation of NaCl from a saturated solution by passing gaseous HCl through it.





## 36. BARIUM, STRONTIUM, CALCIUM (THE ALKALINE EARTH METALS)

\*1. Discuss the general characteristics of the alkaline earth metals.

\*2. Discuss fully the occurrence of Ca compounds in nature.

\*3. How may the metals (Ca, Sr and Ba) be prepared?

4. Give physical and chemical properties of these metals with equations for reactions. How do they differ from the alkali metals?

\*5. Describe a process for the manufacture of "quicklime"; "slaked lime." What is the difference between air-slaked and water-slaked lime?

6. What is mortar? Hydraulic cement? Give uses and properties.

\*7. Describe the manufacture of calcium hypochlorite (chloride of lime). Give equations for reactions. Mention uses.

\*8. Discuss hardness of water, temporary and permanent. How may temporary hardness be overcome? Permanent hardness? Write equations for reactions. Account for caves like the Mammoth Cave in Kentucky.

\*9. Discuss the occurrence, preparation and uses of calcium sulphate.

10. Mention different conditions necessary for the conversion of  $\text{CaCO}_3$ ,  $\text{SrCO}_3$ ,  $\text{BaCO}_3$  to oxides. Compare the behavior of the oxides toward water and give the properties of their solutions.

\*11. Give the properties and uses of  $\text{CaCl}_2$ .

12. Describe the manufacture of lime or crown glass.

\*13. Discuss the properties and uses of  $\text{CaF}_2$  (fluorspar) giving the equation for the reaction in the preparation of  $\text{H}_2\text{F}_2$ .

\*14. Discuss the properties and uses of  $\text{Ca}_3(\text{PO}_4)_2$  (phosphorite), bone ash, guano, etc.

\*15. Describe the manufacture of  $\text{CaC}_2$  and give the uses and properties with equations for reactions.

\*16. Same for calcium cyanamid.

\*17. Discuss the occurrence of strontium compounds in nature.

\*18. Mention the uses of the hydroxide and nitrate.

\*19. Discuss the occurrence of barium compounds in nature.

\*20. Describe Brinn's process for manufacture of  $\text{O}_2$ . How may  $\text{H}_2\text{O}_2$  be prepared from one of the compounds? Write equations for reactions.

\*21. Mention a commercial use of  $\text{Ba}(\text{NO}_3)_2$ .

\*22. Give the flame tests for Ba, Sr and Ca and compare them with tests for the alkalis.

\*23. Compare the solubilities of the sulphates of Ba, Sr and Ca. How do these differences serve as tests for certain of the alkaline earths?

\*24. Give a method for the separation and detection of Ba, Sr and Ca beginning with their chlorides. Write equations for reactions taking place in precipitation and in dissolving the precipitates.

\*25. How many grams of  $\text{H}_2\text{O}$  will be required (theoretically) to convert a pound (453 g.) of plaster of Paris to gypsum?

\*26. Compare the solubility of the salts of the alkalis and alkaline earths.

\*27. Define precipitation in terms of the ion-product constant and saturated solution. On this basis write the equation for the precipitation of calcium as oxalate. Also figure the value for K in the ion product constant formula if the molar solubility of  $\text{CaC}_2\text{O}_4$  is 0.0000043 and an excess of the compound is present.

\*28. On the same basis state the rule for the solution of insoluble substances. At  $18^\circ$   $\text{Ca}(\text{OH})_2$  dissolves to the extent of 0.17 g. per 100 cc.  $\text{H}_2\text{O}$ . Calculate the value for K (constant) in a saturated solution containing an excess of  $\text{Ca}(\text{OH})_2$ . What happens when an acid is added? Why? On the same basis explain the action of HCl on  $\text{CaC}_2\text{O}_4$ .

\*29. Prepare a tabular outline showing the relative solubility of the nitrates, chlorides, sulphates, hydroxides, carbonates, phosphates and chromates in water. When insoluble in water state whether they are soluble in acetic or hydrochloric acid.

\*30. How do you account for the precipitation of certain insoluble salts in the presence of acid?



## 37. COPPER, SILVER, GOLD

- \*1. Discuss the general characteristics of this family.
- \*2. Discuss the occurrence of copper in nature, both free and in combination.
- \*3. How is copper prepared from the sulphide ore? Describe the process and give equations for reactions. Also describe the electrolytic refining of copper.
- \*4. How is  $\text{CuSO}_4$  prepared? What are its uses?
- \*5. Give examples of metals which displace others from solution. What is the electro-motive series? How does it account for displacement?
- \*6. Give the principal alloys of copper with properties and uses. Also mention the principal uses of pure copper. How do impurities affect it for electrical conduction?
- \*7. Give the physical and chemical properties of copper with equations for reactions.
- 8. What is blue vitriol? Green vitriol? White vitriol? Oil of vitriol?
- \*9. Give Faraday's Law with examples showing its application.
- \*10. What is a voltaic cell? How prepared? On what does the voltage depend?
- \*11. Discuss the occurrence of silver in nature.
- \*12. Describe the cyanide process for recovery of silver from ores. Give equations for reactions.
- \*13. Describe the Parkes' Process. Account for the ability to use this process for silver recovery.
- 14. Describe silver plating; the silvering of glass.
- \*15. Give physical and chemical properties of silver with equations for reactions.
- \*16. Discuss the silver halides in their relation to photography. Also  $\text{AgNO}_3$  and its uses.
- \*17. Discuss the alloys of silver, giving their properties and uses.
- \*18. How may silver be separated from gold in alloys?
- \*19. Discuss the occurrence of gold in nature. Name metals known to the ancients and give the probable reasons.
- \*20. Describe the chlorination, cyanide and amalgamation processes for removing Au from ores. Give equations for all reactions. How is gold precipitated from the first two solutions?
- \*21. Give the physical and chemical properties of gold with equations for reactions.
- \*22. Name its principal alloys and give their uses. Define "karat."

\*23. Define colloidal solution. Describe such a solution of gold.

\*24. Write equations representing the action of nitric acid on Cu; on Ag; sulphuric acid on each; aqua regia on Au.

25. How does the color of Au, Ag and Cu in very thin sheets examined by transmitted light, compare with thicker masses?

\*26. Discuss this family on the basis of complex ion formation and give examples.

\*27. Prepare a tabular outline containing metals of this family and their chlorides, nitrates, sulphates and sulphides, showing the relative solubility of the compounds in water, acids or ammonia, as each case may require.

### 38. MAGNESIUM, ZINC, CADMIUM, MERCURY

- \*1. Discuss the occurrence of magnesium compounds in nature.
- \*2. Give a method for the preparation of the element together with its physical and chemical properties.
- \*3. Mention the important compounds and name their uses and those of the element.
- \*4. Give the best tests for the Mg ion in compounds, with equations for reactions.
- 5. How much of the energy comes off in the form of light when Mg burns? How does this compare with other elements?
- 6. Mention two compounds of magnesium which have medicinal use.
- \*7. Discuss the occurrence of zinc compounds in nature.
- \*8. Describe the manufacture of the metal from sphalerite. Give equations for reactions.
- \*9. Give the physical and chemical properties of the element with equations for reactions.
- \*10. Name important alloys of zinc and give their uses.
- \*11. Describe the galvanizing and sherrardizing processes. How do the resulting products differ?
- \*12. Discuss zinc compounds and their uses.
- \*13. Give three tests for zinc in its compounds.
- \*14. Why is ZnO or BaSO<sub>4</sub> paint preferable to "white lead" paint in a manufacturing district?
- \*15. Calculate the amount of zinc which will liberate the same amount of H<sub>2</sub> as 5 grams of Mg. Also the volume of the gas evolved at 23° and 740 mm.
- \*16. Discuss the occurrence and preparation of cadmium and give its properties.
- \*17. Mention uses for the sulphide and sulphate and describe the Weston standard cell. How do you account for the voltage?
- \*18. Give two important tests for Cd (compare Zn).
- 19. Mention important alloys of which cadmium is a component.
- 20. CdO and Fe<sub>2</sub>O<sub>3</sub> are both brown. How can you tell which is Cd?
- \*21. Discuss the occurrence, preparation and purification of mercury.
- \*22. Give the physical and chemical properties of mercury.
- \*23. Mention the principal uses of the element.
- \*24. State the properties and uses of HgCl and HgCl<sub>2</sub>.



**\*25.** Account for the occurrence of Hg, Au, Ag and Cu in the free state. Why do we not find magnesium and zinc as metals?

**\*26.** How can you test for the  $\text{Hg}'$  ion? The  $\text{Hg}''$  ion? Compare Ag.

**\*27.** How much dolomite would be required to give one pound of Epsom salts? How much plaster of Paris will result from the residue?

**\*28.** How much Mg will liberate a gram-molecular volume of  $\text{H}_2$ ? How many gram-molecular volumes of oxygen would convert the Mg to oxide?

**\*29.** Why should  $\text{HgCl}_2$  solution not be kept in metal vessels. Why should  $\text{HgCl}$  be kept in dark bottles?

**\*30.** How does the vapor pressure of Hg vapor compare with that of water vapor? In measuring a gas what pressure correction must be made for the vapors of the confining liquids? Is the value added or subtracted from the barometric reading?

### 39. ELECTROMOTIVE CHEMISTRY

1. List the various units of electrical energy.

\*2. Prepare a sketch of a "combination" cell showing the solutions and metal used and explaining the action in detail. What is the nature of the change which sets up the current? Is the term "combination cell" accurate?

\*3. Prepare a sketch of a "displacement cell" and explain same fully.

\*4. Same for the "oxidation cell."

\*5. Same for the "concentration cell."

\*6. Mention the quantity of electricity produced per equivalent weight of active metal transformed. State a law in which the converse holds.

7. How does the size of the poles influence the rate of production of electricity? How is the E.M.F. of a cell affected by changes in quantity of solution? In quality? In concentration?

\*8. Define single potential differences between metals and illustrate by examples. How is this made use of in displacement cells? Are the values ever very accurate? If so, how are they utilized?

9. Define polarization current; discharging potential.

\*10. Explain the electrolytic refining of copper.

11. Arrange the metals in the order in which they occur in the electromotive series, noting their potentials when in contact with *N* (normal) solutions. State what you would expect in three cells each containing two metals of your own selection in their *N* solutions separated from each other by porous partitions.

\*12. Discuss "Couples" and give examples. How do the properties of "galvanized" iron and "tinned" iron compare and why?

\*13. How do the principles studied in connection with the preceding questions apply in the measurement of chemical affinity?

\*14. Describe the Daniell or gravity cell and explain its action. Should the circuit remain open or closed when the cell is not in use? Why?





## 40. ALUMINIUM AND RARE-EARTH METALS

1. Discuss the rare-earth metals briefly.
- \*2. Discuss occurrence of aluminium compounds in nature.
- \*3. Discuss the manufacture of aluminium, preparing a sketch of apparatus used and explaining same.
- \*4. Give physical and chemical properties of aluminium together with equations for reactions.
- \*5. Mention the uses of the metal. Give the important alloys and their uses.
- \*6. Define mordant and mention aluminium compounds used as mordants.
- \*7. Discuss the hydroxide and oxide including preparation and uses.
- \*8. What is an amphoteric substance? Illustrate by giving examples for zinc and aluminium compounds. How do the metals react with NaOH?
- \*9. How may  $\text{Al}_2(\text{SO}_4)_3$  be prepared? Alum? Give the formula for the latter.
- \*10. Discuss the uses of  $\text{Al}_2(\text{SO}_4)_3$  in water purification and preparation of "lakes."
- \*11. Mention important uses of  $\text{Na}_3\text{AlF}_6$  (cryolite).
- \*12. Describe the Goldschmidt Thermite Process. How can you account for the reaction and temperature? Mention important uses of the process.
- \*13. Give two tests for aluminium in its compounds. Compare them with zinc tests.
- \*14. Calculate the percentage composition of potash feldspar; of cryolite.  $\text{K}=39.1$ ,  $\text{Al}=27.1$ ,  $\text{Na}=23$ ,  $\text{Si}=28.3$ ,  $\text{O}=16$ ,  $\text{F}=19$ .
- \*15. How much aluminium is needed to produce a gram-molecular volume of hydrogen.
- \*16. Why use magnalium for scientific instruments and aeroplane frames, and not Zn or Mg? Compare the alloy with iron and show its advantages over that metal.
- \*17. Compare copper and aluminium as material for the manufacture of cables to conduct electricity. Which would you use and why?
- \*18. What advantage has aluminium leaf over silver leaf for book lettering.
- \*19. Why use aluminium for cooking utensils and not zinc?
- \*20. Why use Zn in preference to Al in batteries?
- \*21. Why is a small piece of aluminium thrown into the ingot mold after pouring steel?
- \*22. Calculate the amount of Au, Cu and Ag which can be precipitated by an electric current which will deposit 81.3 grams of Al.  $\text{Au}=197.2$ ,  $\text{Cu}=63.57$ ,  $\text{Ag}=107.88$ ,  $\text{Al}=27.1$ .

\*23. Why do we not have  $\text{Al}_2(\text{CO}_3)_3$  and  $\text{Al}_2\text{S}_3$  in aqueous solution? Write ionic equations for reactions.

\*24. Discuss kaolin and clay formation and their important uses, including cement and ultramarine manufacture.

\*25. Discuss three principles on which the dyeing of fabrics depends.

\*26. Assuming the specific heat of aluminium oxide ( $\text{Al}_2\text{O}_3$ ) as 0.217, that of iron as 0.15 and the heat of fusion of iron as 23,000 cal. per kilogram, what is the maximum temperature which could be reached by the reaction of a thermite consisting of ferric oxide and metallic aluminium? (Noyes, Textbook of Chemistry.)

## STUDY QUESTIONS FOR INORGANIC CHEMISTRY

### 41. TIN. LEAD

1. Discuss briefly the rarer elements found in group V of the Mendelejeff table.
- \*2. Discuss occurrence of tin in nature. Also the preparation of tin from ores; from scrap.
- \*3. Give physical and chemical properties of tin with equations for reactions.
- \*4. Mention important alloys of tin and give uses. Why should tin foil containing lead not be used to wrap foods?
- \*5. Describe the manufacture of tin plate.
6. Name the oxides of tin telling how they are prepared and giving important uses.
- \*7. Describe the fireproofing of cotton goods through the use of tin salts and tell of other advantages gained from presence of the tin compound formed.
- \*8. Show by equations how stannous chloride serves as a reducing agent.
- \*9. Give two tests for tin (compare Zn).
- \*10. Discuss occurrence of lead compounds in nature.
- \*11. How may lead be prepared from galena? Write equations for reactions.
- \*12. Give physical and chemical properties of lead with equations for reactions.
- \*13. Discuss the oxides of lead. (Methods of preparation, properties and uses, etc.)
- \*14. Describe the Dutch process for the manufacture of white lead.
- \*15. Discuss other compounds of lead (nitrate, chloride, sulphate, sulphide, acetate, chromate, etc.).
- \*16. Give three tests for lead (sulphate, chromate, sulphide). Compare these with tests for silver, mercury and barium.
- \*17. A rectangular block of tin measures  $30 \times 10 \times 5$  cm., and weighs 10,950 g. What is its specific gravity?
- \*18. Why give preference to ZnO paint rather than a Dutch white lead paint in a manufacturing district?
19. Define transition point. How does this help the plumber in soldering?
20. Compare the action of  $\text{HNO}_3$  on lead and tin. Give equations for reactions. If you had a globule of soft white metal and were uncertain as to whether it consisted of tin or lead, how could you determine the composition?
21. Discuss Pb in its relation to the storage battery, giving equations for reactions. How do you account for the holding and discharge of the current?
22. Mention precautions necessary in the use of lead pipe.
23. Calculate the percentage composition of galena and cassiterite.
24. Why use block tin pipe for distilled water conduits and condensers instead of lead or copper?





**42. ARSENIC, ANTIMONY, BISMUTH**

- \*1. Compare nitrogen, phosphorus, arsenic, antimony and bismuth as to valence and oxygen and hydrogen compounds.
- \*2. Discuss the occurrence of arsenic, antimony and bismuth in nature both free and in combination.
- \*3. How may the elements be prepared from their oxides? Give equations for reactions.
- \*4. How may arsenic be prepared from arsenical pyrites? Antimony from sulphide ore?
- \*5. Why class arsenic, antimony and bismuth as quasimetallic substances and not as metals or non-metals? Show by equations how arsenic and antimony may act as metals and non-metals forming compounds characteristic of each.
- 6. Give the allotropic forms of arsenic and antimony with methods for distinguishing between the various forms of each element. Which other element do they resemble in this test for allotropic forms?
- \*7. Mention the most important compounds of arsenic, antimony and bismuth and give their principal uses.
- \*8. Discuss the alloys of these three elements and mention their properties and special uses.
- \*9. Describe the Marsh test for arsenic. How can you tell whether the resulting phenomenon is due to arsenic or antimony? Give equations for reactions.
- \*10. Discuss the hydrolysis of arsenic, antimony and bismuth compounds. Compare same with the halogens of phosphorus. Give equations for all reactions. How can you tell whether the result of the hydrolysis is a bismuth or antimony compound?
- \*11. Define co'loid and crystalloid and give a simple method for distinguishing between a precipitate, a colloid and a perfect solution.
- 12. Mention several methods for overcoming a colloidal condition.
- 13. Prepare a comparative outline of the salts of nitrogen, phosphorus, arsenic, antimony and bismuth.
- \*14. Define acid; base; salt; acid salt; basic salt and give examples.





## 43. CHROMIUM, VANADIUM, TANTALUM, MOLYBDENUM, TUNGSTEN, URANIUM

1. Discuss briefly the rarer elements of this group.
2. Describe the test for vanadium in an acid solution.
- \*3. Mention principal alloy of vanadium, molybdenum and tungsten and their uses. How are these alloys prepared commercially?
- \*4. Give the two principal ores of chromium and compare one to magnetite as to constitution.
- \*5. How are the element and ferrochrome manufactured?
- \*6. Give the physical and chemical properties of chromium. Mention two alloys and their uses.
- \*7. Discuss  $\text{Cr}_2\text{O}_3$  and  $\text{CrO}_3$  as to preparation and properties.
- \*8. How may a chromate be converted into a dichromate? Illustrate by an equation.
- \*9.  $\text{K}_2\text{Cr}_2\text{O}_7$  will oxidize  $\text{FeSO}_4$  to  $\text{Fe}_2(\text{SO}_4)_3$  in the presence of  $\text{H}_2\text{SO}_4$ . Write the equation for this reaction and the one in which  $\text{KMnO}_4$  is used.
- \*10. What is the action of soluble sulphides on aqueous solutions of Cr and Al salts? Write equations for reactions and explain same.
- \*11. Describe two tests for chromium in its compounds.
- \*12. Mention a number of chromium compounds which are used as pigments.
- \*13. What is "chrome alum"? Compare its formula with that of ordinary alum. Define "isomorphism."
14. Describe the test for molybdenum in its compounds.
- \*15. Discuss the occurrence and preparation of tungsten.
- \*16. Give the physical and chemical properties of tungsten and its principal uses.
17. Discuss the occurrence and preparation of uranium.
18. Give the physical and chemical properties of the element together with the principal uses of the compounds.
19. Compare Columbium, Tantalum and Tungsten as to light-giving properties with the same electric current.
- \*20. Calculate the quantity of  $\text{FeSO}_4$  which can be oxidized to  $\text{Fe}_2(\text{SO}_4)_3$  by a gram-molecule of  $\text{K}_2\text{Cr}_2\text{O}_7$ . How does this compare with the amount for a gram-molecule of  $\text{KMnO}_4$ ?
- \*21. Define acid; base; salt; acid salt; basic salt. Give examples.
- \*22. Define oxidation; reduction. Give examples.
- \*23. Define hydrolysis. Give examples.



#### 44. RADIUM

- \*1. Compare the chemical properties of radium and its compounds with those of the other alkaline-earth metals.
2. Discuss the history of radium and radio activity.
3. Where is radium found and how may it be separated from its ores?
- \*4. Show graphically various kinds of rays emitted by Ra compounds and the effect of a magnet on same.
- \*5. What is an electron? A cathode ray particle? How do these compare with ordinary light rays?
6. Discuss the various Crookes' tubes used in cathode ray experiments.
- \*7. Describe the spinthariscopes and explain the phenomenon observed.
- \*8. How do temperature changes affect the disintegration of radium atoms?
- \*9. What effect do the rays have on air? On minerals like sphalerite?
- \*10. What are the physiological effects of the rays? How are they utilized? What precautions must be taken in handling radium compounds? How are they preserved?
- \*11. How does the temperature of a radium compound compare with that of its surroundings? How much heat is evolved per hour per gram of radium?
- \*12. What is meant by the "half life" of an element? Give an example.
- \*13. What can you say of the penetration of opaque substances by the rays? Do they all have the same penetrating power? How may they be separated roughly?
- \*14. Which element is the "parent" of Ra? What are some of its decomposition products?





### 45. MANGANESE

1. Mn is the only element in family 1, group VII of the periodic table. Can you predict others yet to be discovered and tell what their properties will be?

\*2. How does the element resemble the halogens?

\*3. Discuss the occurrence of manganese in nature.

\*4. How may the metal be prepared from pyrolusite?

\*5. Give physical and chemical properties of manganese with reactions.

6. Discuss alloys of manganese and mention their uses.

\*7. Define catalytic agent and give several examples.

\*8. Potassium permanganate is of importance in analytical chemistry. Give a reaction which illustrates its use.

\*9. Which has the greatest oxidizing power if 10 grams each of the following are taken:  $\text{KMnO}_4$ ,  $\text{K}_2\text{Cr}_2\text{O}_7$ ,  $\text{PbO}_2$ ,  $\text{BaO}_2$ ? How much ferrous salt would be converted to ferric salt by a gram-molecule of each. Answer the last question in gram-molecules.

\*10. Describe an important fusion test for Mn; the bead test. Mention a precipitation test which is characteristic of Mn and give equations for reactions.

\*11. How do you account for the ability of aluminium to reduce  $\text{MnO}_2$ ?

12. How do you account for the decolorization of glass, which would otherwise have a greenish color, when  $\text{MnO}_2$  is mixed with the raw material. How do the colors of  $\text{Fe}^{++}$  and  $\text{Fe}^{+++}$  differ in aqueous and vitreous solutions?

\*13. How much  $\text{MnO}_2$  is necessary for the preparation of a gram-molecular volume of  $\text{O}_2$ ? How much  $\text{KMnO}_4$ ?

\*14. Define acid; base; salt; acid salt; basic salt. Give examples.

\*15. Define oxidation; reduction. Give examples.





### 46. IRON, NICKEL, COBALT

- \*1. Discuss occurrence of iron in nature. How do you account for native iron?
- \*2. Give physical and chemical properties of pure iron with equations for reactions.
- \*3. Which ores of iron are used for the manufacture of the metal on a commercial scale. Why not include pyrites?
- \*4. Describe the preparation of pig iron in the blast furnace. Prepare a sketch of the furnace and accessories, lettering parts and naming their functions.
- \*5. What double function does limestone have in the process?
- \*6. Tell fully what is done with the gases escaping from the furnace.
- \*7. What advantage is derived from heating the air before sending it through the tuyeres? From cooling the air before sending it through the stoves?
- \*8. Describe the method used for manufacture of open-hearth steel both basic and acidic. Why use a basic lining for some steels? What is sometimes done with the basic lining when its composition has been changed by use?
- \*9. Describe the Bessemer process for making steel.
- \*10. Describe the manufacture of wrought iron. Name drawbacks of the method.
- \*11. Describe the cementation or crucible process for manufacture of special steels.
- 12. Ni, Cr, Mn, Al, Si, W, Ti, V, C, Mo and Cu are used in special steels. Mention the special properties for which some of these steels are prized.
- \*13. Discuss the allotropic forms of iron. How do you account for hardening of steel by chilling? What happens in the so-called self-hardened steels?
- \*14. Compare the impurities in iron with those in steel.
- \*15. Mention the most important compounds of iron and their uses.
- \*16. How can you test for the  $\text{Fe}^{++}$  ion? For the  $\text{Fe}^{+++}$  ion? Give equation for reaction.
- \*17. Discuss the occurrence and preparation of nickel and cobalt.
- \*18. Give the physical and chemical properties of nickel and cobalt.
- \*19. Mention an important use of  $\text{CoO}$ . What are the most important uses of nickel?
- \*20. Give the best test for the Ni ion; the Co ion. Write equations for reactions.
- \*21. Give the color of ferrous salts; ferric salts; cobalt salts; nickel salts.
- \*22. Describe a good method for nickel plating.
- \*23. What causes the rusting of iron? Prove that two agents are responsible for the action.
- \*24. Calculate the amount of iron obtainable from a ton of haematite running 70 per cent Fe. Also the amount of coke and air needed to reduce the ore and furnish a gas containing 11.4 per cent  $\text{CO}$ . How much nitrogen should be found in the mixture of gases resulting?



47. THE PLATINUM METALS

1. Discuss briefly the preparation and properties of the rare metals related to platinum.
- \*2. Mention the special properties of platinum which make it a useful metal in the laboratory and industries.
- \*3. Discuss the preparation and properties of the metal and of  $\text{PtCl}_4$ .
- \*4. How would you test for Pt in its compounds?
- \*5. Why did the War Department (during the European War) request jewelers to refrain from using platinum for setting precious stones?
- \*6. Define catalytic agent and give three examples.
- \*7. Define adsorption preparing an ideal sketch which accounts for the property in solids. Mention several substances which display the property to a marked degree. Cite a use for platinum which depends on this property.





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9		—	—	Er = 167.7	—	Yb = 173.5	—	—	
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11		Au = 197.2	Hg = 200.6	Tl = 204.0	Pb = 207.20	Bi = 208.0			
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